Formal Property Verification of the Digital Section of an Ultra-Low Current Digitizer ASIC

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accellera SYSTEMS INITIATIVE™

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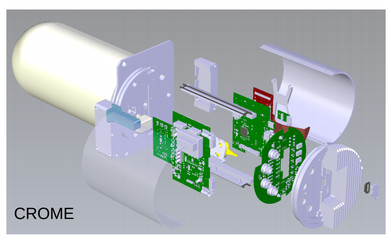
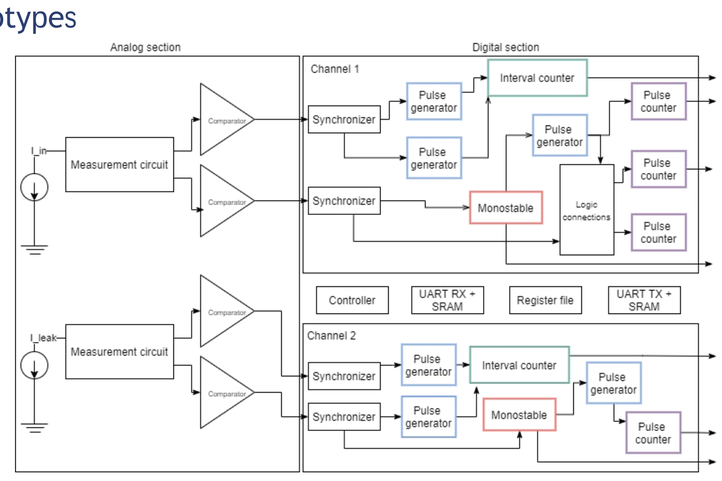
INTRODUCTION

- CERN (European Organization for Nuclear Research) conducts particle physics experiments which produce radiation
- Radiation Protection Group is responsible for measuring levels of ionizing radiation and for ensuring radiological safety of people

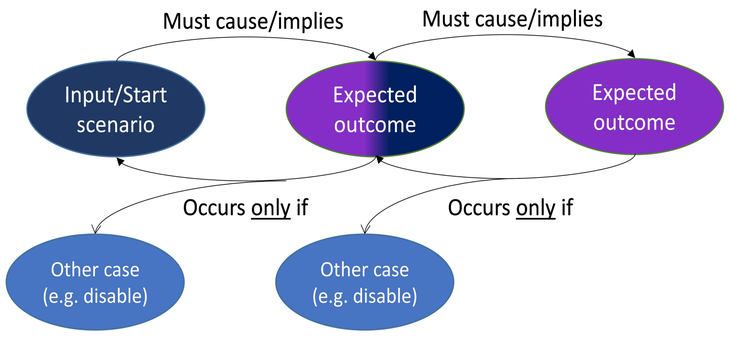
- Aim of this work: Demonstrate examples of Formal Property Verification of the digital section of the ASIC prototypes for the future front end of the CERN RadiatiOn Monitoring Electronics (CROME)

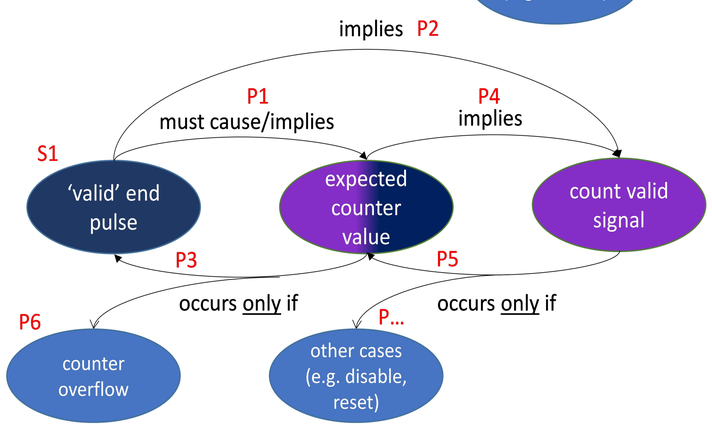




Chain of Events

- Challenges:
  1. Sequential nature - Input current is determined by several counters of up to 40 bits
  2. Many corner cases





- Analyze requirements as chain of events
- Use properties of short sequential depth to express relationship between 2 events

Proving the Current Counters

Counting with Local Variables

```
assert property(
 reg[`Bit_Width - 1:0] lCnt; // local counter
 (((cond1, lCnt = 1) or (cond2 or cond3, lCnt = 0))[*0:$]
    ##1
 ((cond4, lCnt++) or (cond5, lCnt = lCnt))[*0:$]
    ##1
 ((cond6, lCnt = lCnt) or (cond7, lCnt = 1)))
 |=> (lCnt == duvCnt);
);
```

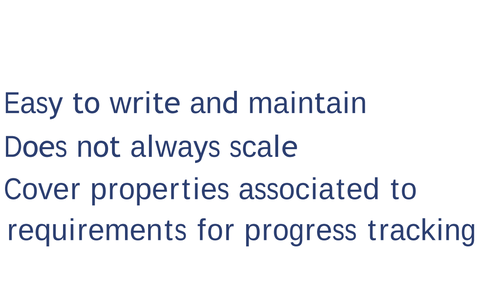
- Hard to write, read and debug
- Scaled better than Reference Models
- Cover properties to ensure that all 'or' branches in antecedent are reachable

Two Clock Cycle Property

```
assert property(
  // Normal counting
    counter == $past(counter) + 1 ||
  // Case 1: counting not started
    ( ($past(counter) == 0 ||
  // Case 2/3: counter should reset
     $past(counter) == $past(targetValue) ||
     otherCondition)
    && counter == 0 )
);
```

- Property describes full requirement
- Very efficient, exhaustive proof within seconds
- Only for counters with few input dependencies

Reference Models



- Easy to write and maintain
- Does not always scale
- Cover properties associated to requirements for progress tracking

CONCLUSIONS

- Safety standard compliant methodology including
  - detailed specification
  - requirements based progress tracking
  - regular review meetings
  → lead to early fault discoveries and less debugging effort
- Wrong property affects larger part of the functionality than a wrong test case
  → quality assurance techniques necessary
- Structural coverage with reduced bit-width does not reveal cases where small values/bit-widths are mistakenly hard-coded → add functional coverage
- Counter examples recreated in simulation by designer for analysis and bug fixing

- Chain-of-Events-based requirements analysis lead to efficient properties
- Properties with small structural size and short sequential depth do not guarantee fast proof results
- Counters: Each method has its strengths/weaknesses and applicability
- Formal with synthesis semantics is closer to silicon than simulation
  → revealed 'X' values inside the design

- Found 30 faults, many corner cases
- Proved 70 properties
- Detailed examples of properties and results in the paper

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