HARDWARE RSA ACCELERATOR

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OBJECTIVE

- Implement the RSA cryptology algorithm in Bluespec on the XUPV5 FPGA
  - 1024-bit keys for higher security
  - Meet 50 MHz timing and beat RaspberryPi performance

RSA ENCRYPTION AND DECRYPTION IN HARDWARE

- Benefits
  - Allow device manufacturers to skip inclusion of processors in devices that only require RSA
  - Improved performance, power usage, space

- Cool Application Example
  - Intelligence agencies' covert listening devices (bugs) with secure communication through RSA

ALGORITHM OVERVIEW

- Components:
  - Public Key (n, e)
  - Private Key (n, d)
  - Plaintext Message (m)
  - Ciphertext (c)

- Encryption

$$c \equiv m^e \ (mod\ n)$$

- Decryption

$$m \equiv c^d (mod\ n)$$

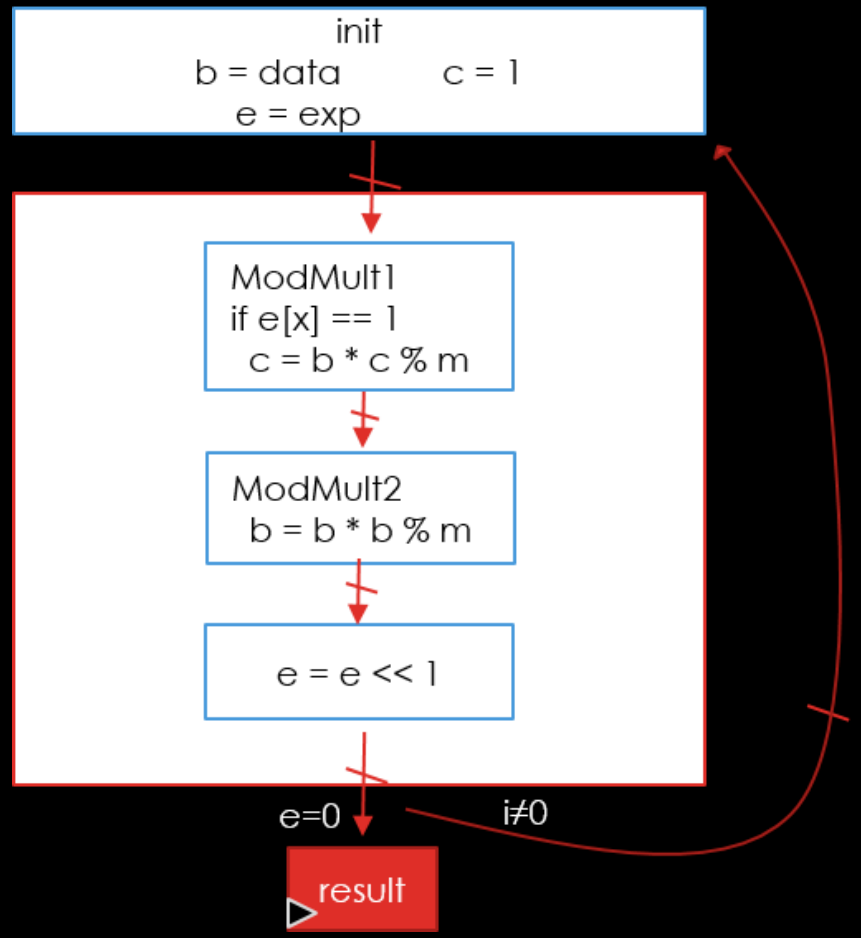
$$data^{exponent}\ (mod\ modulus)$$

IMPLEMENTING $data^{exponent} \ (mod\ modulus)$

- Modular Exponentiation
  - Right to Left binary algorithm
  - Computed using a Modulus Multiplication

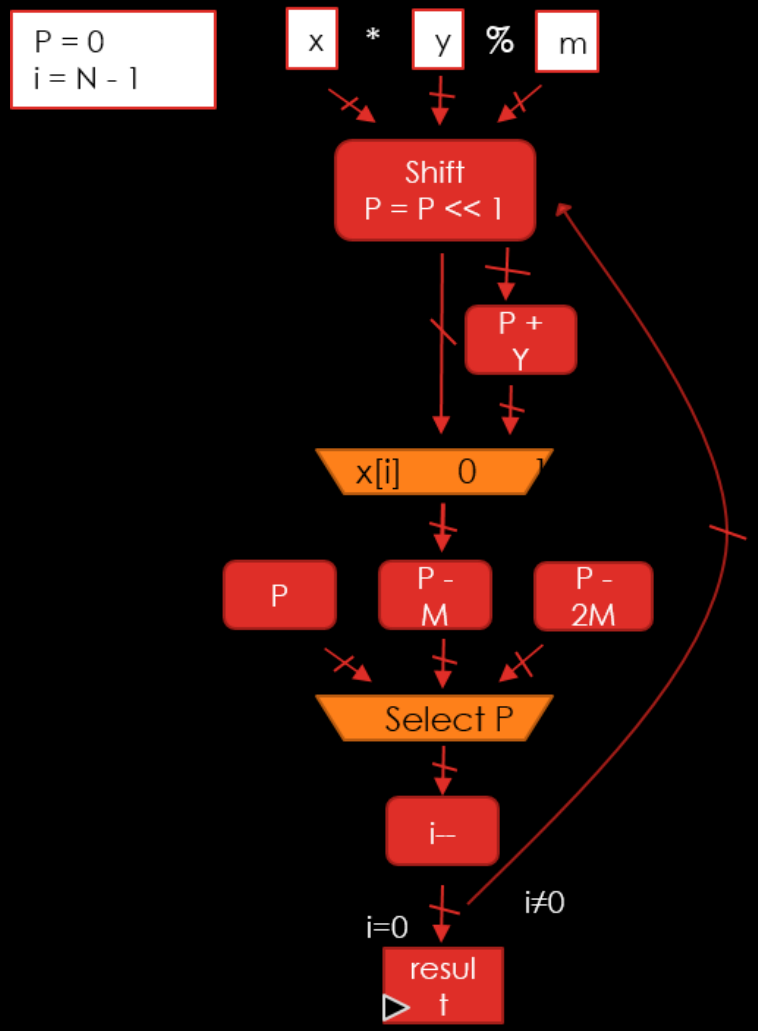
- Interleaved Modulus Multiplication
  - Multiplication that interleaves the modulus that requires binary shifts, bitwise operations, and additions

MODULAR EXPONENTIATION



- Performs left-right binary exponentiation
- Uses two modular multipliers
- Takes 1024 steps to complete

INTERLEAVED MODULAR MULTIPLICATION



- Performs
  A * B mod M
- Scans through bits of A, if A[i] is 1, then adds the value of B
  - Then corrects for modular overflow
- Optimized to prevent long comparison chain

ADDER DESIGN EXPLORATION

- Objective: to meet 50 MHz for a 1024-bit add

- Solution:
  - **Naïve ripple-carry adder**
    - Did not meet timing
  - **Carry look-ahead adder**
    - Clocked at 83.5 MHz
  - **Multi-cycle adder**
    - Lower performance than CLA
  - **Reduced clock frequency adder**
    - Did not meet space constraints

TIMING RESULTS

- Achieved 84.5 MHz for 1024-bit RSA (clocked at 50MHz)
  - Completes operation in ~200ms
- Raspberry Pi (700 MHz ARM11) completes an operation in one minute
  - Significant improvement over embedded processors

CONTRIBUTION

- Exceeds RaspberryPi performance using less power: **1.8 W** consumption
- RaspberryPi utilizes **2 W**
- Parametrizable adder architectures:
  - Carry look ahead, multicycle adder modules