TOPIC: 6.857

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Admin:

Pset #2 is out, due Wed 3/24

Projects! (Post ideas on Piazza, ...)

Today:

Constructing Hash Fns:

(1) Merkle-Damgard (MD5, SHA2)

(2) "Sponge" construction of SHA-3

Readings:

(for this part)

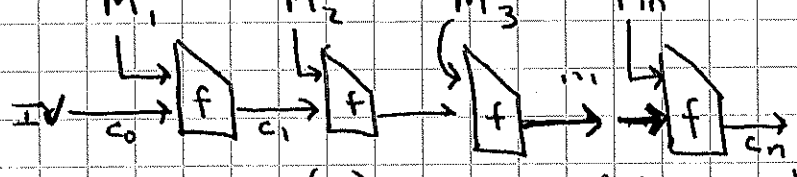
Wikipedia: Merkle-Damgard
SHA-3

Merkle-Damgard Construction

- Choose output size d (e.g. $d = 256$ bits)
- Choose "chaining variable" size c (e.g. $c = 512$ bits)
  (Make $c \geq 2d$ for good security)
- Choose "message block size" b (e.g. $b = 512$ bits)
- Design "compression function" f
  $f: \{0,1\}^c \times \{0,1\}^b \to \{0,1\}^c$
  [f should be OW, CR, PR, TCR, NM, ...]
- Merkle Damgard is essentially a "mode of operation" allowing for variable-length inputs:
  * Choose a c-bit initialization vector IV, c_0
    (c_0 is fixed & public)
  * [Padding] Given message, append
    - at least one "1" bit, then
    - enough "0" bits so result is a multiple of b bits after concatenation of length of message too.

$M = M_1 M_2 \cdots M_n$ (n b-bit blocks)

Then



$h(m) = c_n$ truncated to d bits

Thm: If f is CR, then so is h.

PF: Given collision for h, can find one for f by working backwards through chain ☒

Thm: Same for OW.

Common design pattern for f:

$$f(c_{i-1}, M_i) = c_{i-1} \oplus E(M_i, c_{i-1})$$

where $E(K, M)$ is an encryption function (block cipher) with b-bit key and c-bit input/output blocks.

(See Wikipedia for more details on MD5.)

SHA-3 (Keccak)

Different construction: "sponge" construction
- Can add entropy (message blocks) at any time
- Can extract output (squeezesponge) at any time

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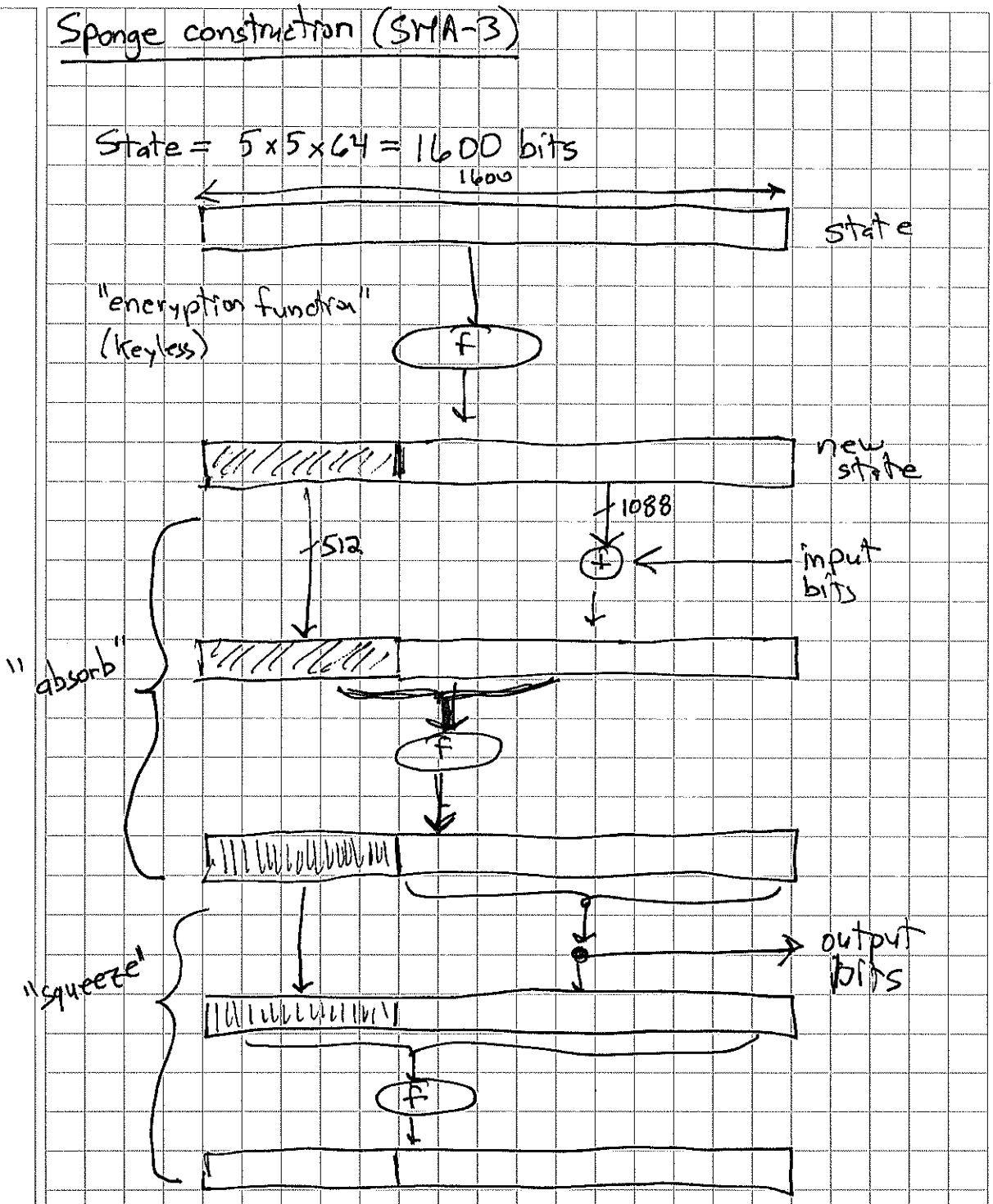
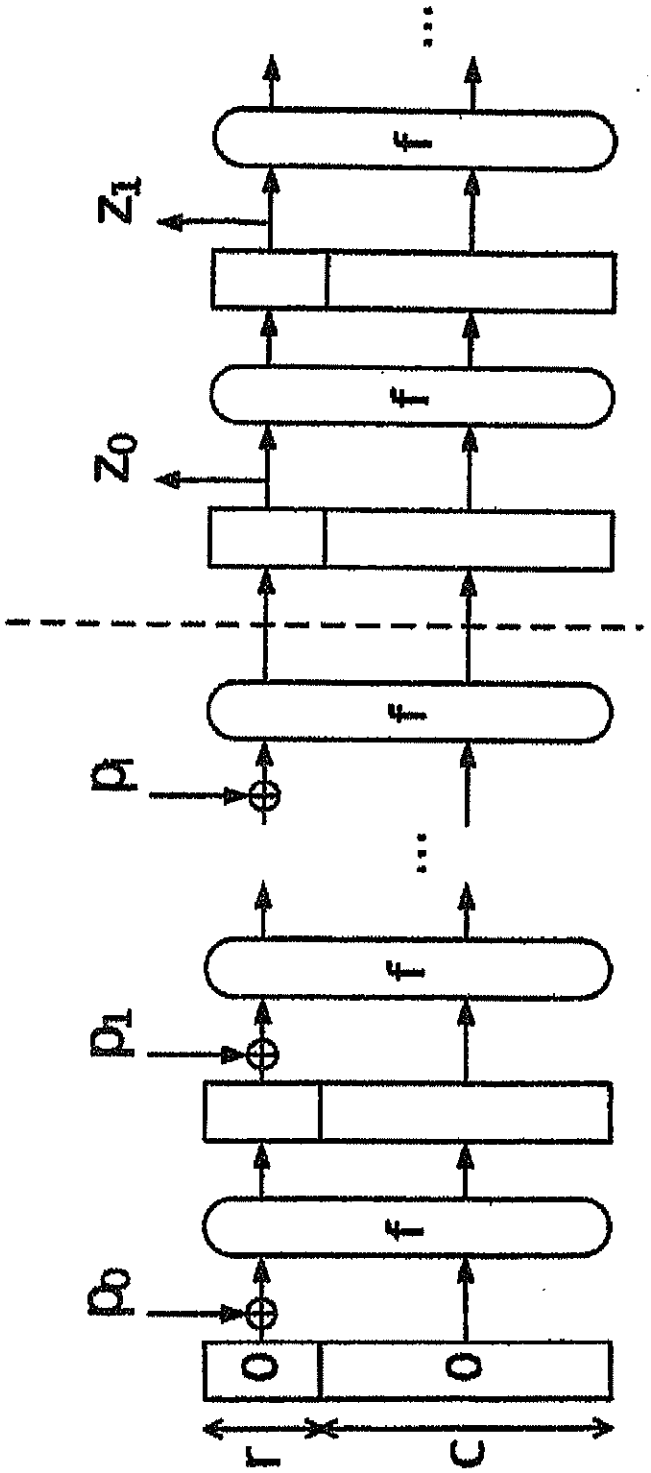
Sponge construction (SHA-3)



Keccak = SHA-3



Keccak Sponge Construction

d = output hash size in bits $\in \{224, 256, 384, 512\}$

c = 2d bits

state size = 25 w where w = word size (e.g. w = 64)

c + r = 25w

r ≥ 8d (so hash can be found d bits of z_0)

Input padded with 10^*1 until length is a multiple of r

f has 24 rounds (for w = 64), not quite identical (round constant)

f is public, efficient, invertible function from $\{0,1\}^{25w} \to \{0,1\}^{25w}$

e.g. d = 256
c = 512
r = 1088
w = 64