

Digital Logic and Computer Organization

Number Systems and Codes

Integers

- Base n representation
- Base 2 representation of negative integers
 - sign magnitude
 - 1's complement
 - 2's complement
- Binary-Coded-Decimal (8421 code) for integers
- Gray code

Characters

- ASCII
- EBCDIC
- Unicode

System Defects

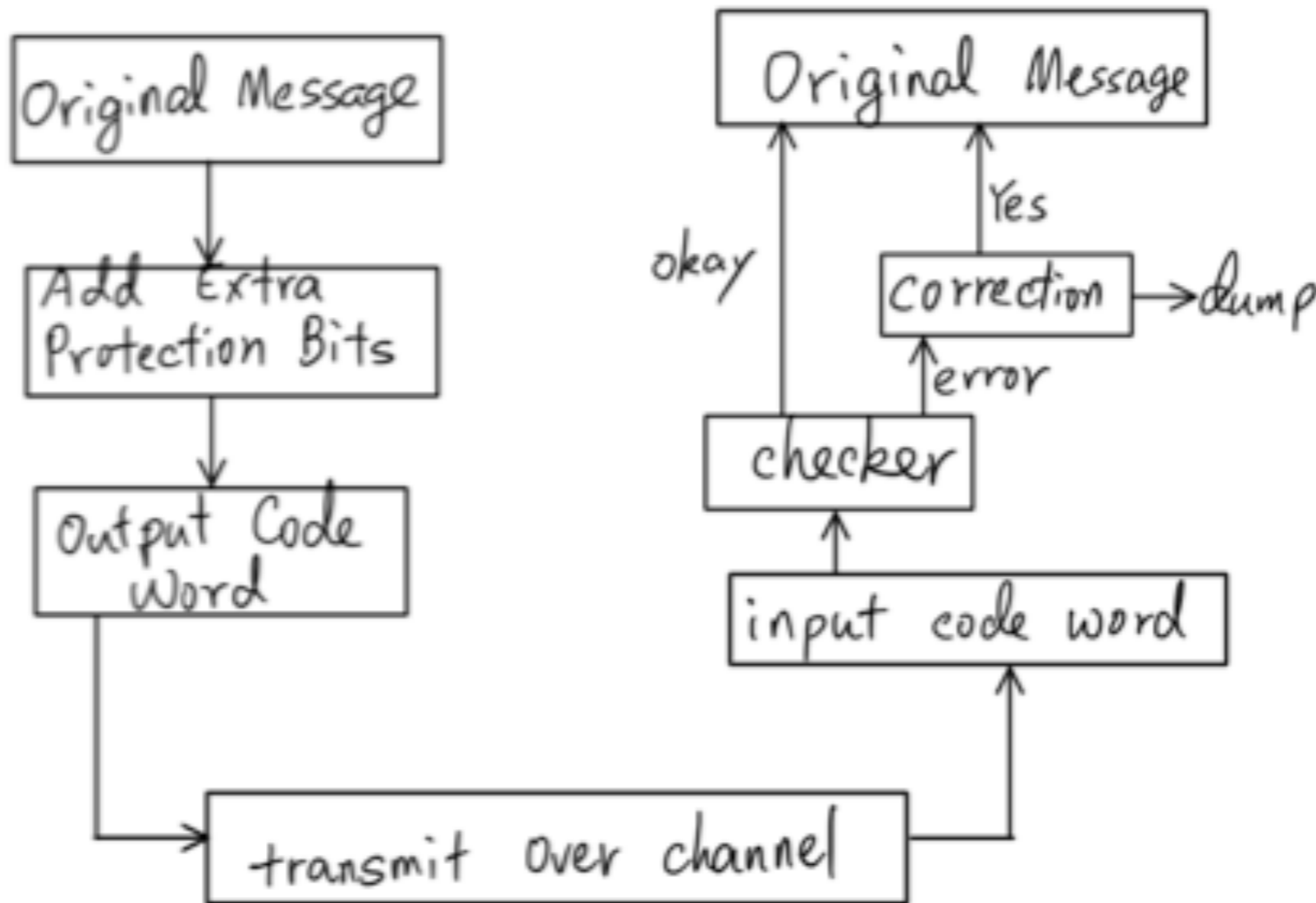
- Fault is a flaw
- Error is an observable difference between actual output and expected output
 - Dijkstra: program testing can only be used to show the presence of bugs and not their absence
- Failure is the inability of the system (or component) to perform its required function according to its specification

Data Communication

Faults/Errors

- Faults
 - Interference: E.M. radiation
 - Distortion: medium blocks some frequencies
 - Attenuation: signal becomes weaker over long distances
 - Protocol mismatch: big-endian vs. little-endian
- Errors
 - single bit errors
 - Burst (multi bit) errors
 - erasure (ambiguity)

Error Detection/Correction

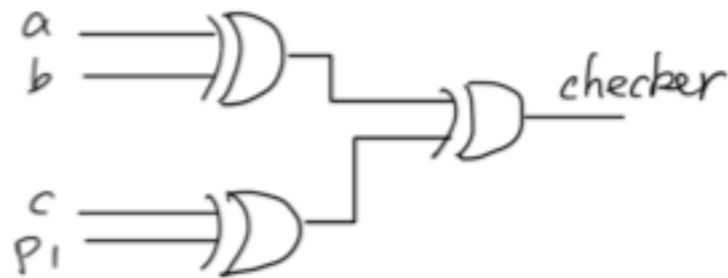


Error Codes

- Parity bit
- Even parity generator



- Even parity checker



Hamming Codes (Turing Award 1968)

- Single bit error correction
- use r parity bits to protect $(2^r - r - 1)$ data bits
 - number the bits' positions from 1
 - bits in the position of powers of 2 are parity bits (p_1 in position 1, p_2 in position 2, p_3 in position 4, p_4 in position 8, and so on)
 - rest bits are data bits
- Generator: $P_i = \bigoplus$ all bits whose i 's position is 1
- Checker: $C_i = P_i \bigoplus$ all bits P_i covers
- Syndrome: ... $C_3 C_2 C_1$ collectively referred to as the syndrome

Extended Hamming Code

- single bit error correction
- double bit error detection
- example, when $r = 3$ to protect 4 data bits, add an extra parity p_4
- $p_4 = p_1 \oplus p_2 \oplus d_1 \oplus p_3 \oplus d_2 \oplus d_3 \oplus d_4$
- $c_4 = p_4 \oplus p_1 \oplus p_2 \oplus d_1 \oplus p_3 \oplus d_2 \oplus d_3 \oplus d_4$

Syndrom and c4 Inference

- $c4 = 0$ and syndrome $= 0 \Rightarrow$ no error
- $c4 \neq 0$ and syndrome $\neq 0 \Rightarrow$ single bit error (can be corrected)
- $c4 = 0$ and syndrome $\neq 0 \Rightarrow$ double bit error (detected, but can't be corrected)
- $c4 \neq 0$ and syndrome $= 0 \Rightarrow p4$ in error

Burst Errors

- Pick a fixed width, wrap data bits in lines
- Form Hamming blocks along the “vertical” direction rather than the “horizontal” direction

