

Midterm Exam of Error-Correcting Codes

Nov. 11, 2021

1. (a) (4%) Determine whether $X^7 + 1$ is irreducible over $GF(2)$ or not.
 (b) (4%) Determine whether $X^4 + X^3 + X^2 + X + 1$ is irreducible over $GF(2)$ or not.
 (c) (4%) Let α be a primitive element of $GF(64)$ with $1 + \alpha + \alpha^6 = 0$. Determine whether $X^2 + X + 1$ is irreducible over $GF(4)$ or not.
 $\alpha^6 = 1 \Rightarrow (\alpha^{21})^3 = 1$
 $\alpha^6 = 1 \Rightarrow \alpha^{21} = 1$
2. Consider a primitive element of the finite field $GF(2^6)$ for which $1 + \alpha + \alpha^6 = 0$.
 (a) (4%) Find all the field elements of $GF(2^6)$ of order 9.
 (b) (4%) Express α^{15} in polynomial form.
 (b) (4%) Find the binary minimal polynomial of α^9 .
 $\alpha^9 \cdot \alpha^{18} \cdot \alpha^{36} \cdot \alpha^{72} = 1$
 $\alpha^{15} = (\alpha^6)^2 \alpha^3 = (\alpha^{12} + 1) \alpha^3 = \alpha^{15} + \alpha^3$
 $= \alpha^3 + \alpha^3 = 0$
3. Let α be a primitive element in $GF(2^{11})$.
 (a) (4%) Show all the conjugates of α over $GF(2)$.
 (b) (4%) Find an element in $GF(2^{11})$ which is a primitive 23rd root of unity.
 (c) (4%) Find the BCH bound of the binary cyclic code for which its generator polynomial is the minimal polynomial of α .

4. Consider an (n, k) binary BCH code with error-correcting capability t .
 $g(X)$ with deg. $n-k=45$

- (a) (4%) Let $n = 63$ and $k = 18$. Please find its t .
 $1 \cdot 2 \cdot 4 \cdot 8 \cdot 16 \cdot 32$
- (b) (4%) Let $n = 127$ and $t = 9$. Please find its k .
 3
- (a) (5%) Let $g(X) = (1 + X)(1 + X + X^4)$ be the generator polynomial of an $(15, 10)$ binary cyclic code C . Find a generator matrix of C .
 $n-k=5$
- (b) (5%) Find a parity check matrix of C .
 $n-k=5$
- (c) (5%) Use $g(X)$ to systematically encode the message $u(X) = 1 + X^3$ into a codeword of C .

- (6) (8%) State and prove the Singleton bound.
 $A(X) = A_0 + A_1 X + \dots + A_{n-1} X^{n-1}$
 $G = [P | I_k]$
- (7) (10%) Prove that the Reed-Solomon code defined by $C = \{\bar{a} = A(\alpha^i), i = 0, 1, \dots, n-1\}$, where $\deg A(X) < k$, is an (n, k) cyclic code with $n - k$ consecutive roots.
 $u(X) = \sum_{i=0}^{n-1} u_i X^i$
 $g(X) = \prod_{i=1}^{n-k} (X - \alpha^i)$
 $u(X) = g(X)u_1(X)$

8. (8%) Let $g(X)$ be the generator polynomial of an (n, k) cyclic code C . Suppose C is interleaved to a depth of λ . Prove that the interleaved code C^λ is also cyclic and its generator polynomial is $g(X^\lambda)$.
 $u(X) = g(X)u_1(X)$
 $u_1(X) = g_1(X)u_2(X)$
 $u_2(X) = g_2(X)u_3(X)$
 $u_3(X) = g_3(X)u_4(X)$
 $u_4(X) = g_4(X)u_5(X)$
 $u_5(X) = g_5(X)u_6(X)$
 $u_6(X) = g_6(X)u_7(X)$
 $u_7(X) = g_7(X)u_8(X)$
 $u_8(X) = g_8(X)u_9(X)$
 $u_9(X) = g_9(X)u_{10}(X)$
 $u_{10}(X) = g_{10}(X)u_{11}(X)$
 $u_{11}(X) = g_{11}(X)u_{12}(X)$
 $u_{12}(X) = g_{12}(X)u_{13}(X)$
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