Quadratic functions with prescribed spectra

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Abstract. We study quadratic Boolean functions f from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$, which are well-known to have plateaued Fourier spectrum $\mathcal{F}_{s,f}$, i.e., their Fourier coefficients are in the set $\{0, \pm 2^{(n+s)/2}\}$ for some integer $0 \le s \le n-1$. For various types of integers n, we determine possible values of s, construct f with $\mathcal{F}_{s,f}$ for a prescribed s, and present enumeration results in case n is a power of 2.
Our work generalizes some of the earlier results of Khoo et. al. ([5]) on near-bent functions and provides a simple proof of a result of Fitzgerald ([2]) on degenerate quadratic forms.

Keywords: Quadratic Boolean functions, s-plateaued functions, near-bent functions, self-reciprocal polynomials, linear complexity

1 Introduction

We study quadratic functions

$$f(x) = \mathrm{Tr_n}\left(\sum_{i=0}^{\lfloor (n-1)/2 \rfloor} a_i x^{2^i+1}\right) \tag{1}$$

from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$, with coefficients in $\mathbb{F}_2$.

It is well known that any quadratic function is *plateaued* i.e., it has (plateaued) Fourier spectrum

$$\mathcal{F}_{s,f}$$

, in other words, its Fourier coefficients lie in $\{0, \pm 2^{(n+s)/2}\}$ for some integer $0 \le s \le n-1$. In this case we call f *s-plateaued.* 1-plateaued functions have been widely studied, and are called *near-bent* or *semi-bent* (when n is odd), see for instance [1, 6].

One of the problems, that [5] focuses on, is to characterize integers n, for which all f from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$ of the form (1) are near-bent.

The more general question we address here is the following: Given an integer n, characterize those integers s, for which s-plateaued functions from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$ of the form (1) exist. We obtain the characterization when n is a square-free integer or is a power of 2. For these classes of integers n, we give methods for constructing s-plateaued functions for all possible s. We also enumerate the s-plateaued functions in case $n = 2^m$, $m \geq 1$.

Using standard Welch-squaring techniques one can see that the integer s is the dimension over $\mathbb{F}_2$ of the kernel of the linear transformation defined on $\mathbb{F}_{2^n}$ by

$$L(x) = \sum_{i=0}^{\lfloor (n-1)/2 \rfloor} \left(a_i x^{2^i} + a_i^{2^{n-i}} x^{2^{n-i}} \right),$$

i.e., $\gcd(x^{2^n} + x, L(x))$ has degree 2^s. Equivalently $ker(L)$ has dimension s if and only if the associates $A(x)$ and $x^n + 1$ of $L(x)$ and $x^{2^n} + x$, respectively, satisfy (see [7, p.118])

$$\deg(\gcd(A(x), x^n + 1)) = s.$$

The associate $A(x)$ corresponding to f in (1) is

$$A(x) = \sum_{i=0}^{\lfloor (n-1)/2 \rfloor} a_i x^i + a_i x^{n-i} = x^{i_0} g(x), \tag{2}$$

where i_0 is the smallest integer such that $a_{i_0} \neq 0$, and $g(x) \in \mathbb{F}_2[x]$ is the self-reciprocal polynomial

$$g(x) = \sum_{i=i_0}^{\lfloor (n-1)/2 \rfloor} a_i (x^{i-i_0} + x^{n-i_0-i})$$

of degree $n - 2i_0$.

Note that $\gcd(\sum_{i=0}^{\lfloor (n-1)/2 \rfloor} a_i x^i + a_i x^{n-i}, x^n + 1) = \gcd((\sum_{i=1}^{\lfloor (n-1)/2 \rfloor} a_i x^i + a_i x^{n-i}) + a_0(x^n + 1), x^n + 1)$, i.e., a_0 does not effect the value of s. Hence we can suppose that the degree of $A(x)$ is at most $n - 1$.

We recall that the linear complexity $L(S)$ of an n-periodic sequence $S = s_0, s_1, \ldots$ over $\mathbb{F}_2$ is determined by

$$L(S) = n - \deg(\gcd(x^n + 1, S(x)))$$

where $S(x)$ is the *generating polynomial* of S, i.e., the polynomial of degree at most $n-1$ given by $S(x) = s_0 + s_1 x + \cdots + s_{n-1} x^{n-1}$. Therefore the calculation of the values in the Fourier spectrum of a quadratic function (1) is equivalent to the determination of the linear complexity of an n-periodic sequence with generating polynomial of the form (2). More precisely $s = n - L$ if L is the linear complexity of the corresponding n-periodic sequence.

2 Main Results

2.1 The case $n = 2^m$

In this subsection we will employ the well known Games-Chan algorithm (see [3]) to enumerate the functions (1) from $\mathbb{F}_{2^{2^m}}$ to $\mathbb{F}_2$ that yield s-plateaued functions. The algorithm also leads to a tool of constructing s-plateaued functions for a given s.

The following example describes how one can calculate s.

Example 1. For $m = 4$ consider $f(x) = \mathrm{Tr_n}(x^2 + x^3 + x^{2^4+1} + x^{2^5+1})$, then $A(x) = 1 + x + x^4 + x^5 + x^{11} + x^{12} + x^{15} + x^{16}$. For our purpose we consider this polynomial modulo $x^{16} + 1$ and put

$$A(x) = x + x^4 + x^5 + x^{11} + x^{12} + x^{15}$$

and obtain the corresponding 16-periodic binary sequence

$$S = (0100110000011001)^\infty.$$

$$\begin{array}{c} 0\,1\,0\,0\,1\,1\,0\,0 \\ 0\,0\,0\,1\,1\,0\,0\,1 \\ \hline 0\,1\,0\,1\,0\,1\,0\,1 \\ L = 8 \end{array} \qquad \begin{array}{c} 0\,1\,0\,1 \\ 0\,1\,0\,1 \\ \hline 0\,0\,0\,0 \\ L = 8 \end{array}$$

$$\begin{array}{c} 0\,1 \\ 0\,1 \\ \hline 0\,0 \\ L = 8 \end{array} \quad \begin{array}{c} 0 \\ 1 \\ \hline 1 \\ L = 9 \end{array} \quad L = L + 1 = 10.$$

As the 16-periodic sequence S corresponding to $A(x)$ has linear complexity $L = 10$, the quadratic function f is s-plateaued with $s = 16 - 10 = 6$.

The Games-Chan algorithm motivates the definition of a mapping φ_m from $\mathbb{F}_2^{2^m}$ to $\mathbb{F}_2^{2^{m-1}}$, $m \geq 1$, as follows:

$$\varphi_m((s_0, s_1, \ldots, s_{2^m-1})) = (s_0 + s_{2^{m-1}}, s_1 + s_{2^{m-1}+1}, \ldots, s_{2^{m-1}-1} + s_{2^m-1}).$$

In the following proposition we collect some simple observations for 2^m-periodic sequences corresponding to polynomials $A(x)$ in (2) with $n = 2^m$. As remarked above we can assume that $a_0 = 0$, thus $\deg(A) \leq n - 1$. The strings $\mathbf{s}^{(m)} = s_0, s_1, \ldots, s_{2^m-1}$ of our interest can easily be seen to satisfy $s_0 = s_{n/2} = 0$, $s_i = s_{n-i}$, $i = 1, \ldots, n/2 - 1$. We will call a string satisfying these properties *antisymmetric*. Accordingly, we call the corresponding sequence antisymmetric 2^m-periodic sequence.

Proposition 1. *Let* $\mathbf{s}^{(m)} = s_0, s_1, \ldots, s_{2^m-1}$ *be a string,* $m \geq 1$.

(i) An antisymmetric string $\mathbf{s}^{(m)}$ *is determined by the bits* $s_1, \ldots, s_{2^{m-1}-1}$. *There are* $2^{2^{m-1}-1}$ *distinct antisymmetric strings of length* 2^m.

(ii) If $\mathbf{s}^{(m)}$ *is antisymmetric, then* $\varphi_m(\mathbf{s}^{(m)})$ *is also.*

(iii) The set of antisymmetric preimages $\varphi_m^{-1}(\mathbf{s}^{(m-1)})$ *of an antisymmetric string* $\mathbf{s}^{(m-1)}$ *has cardinality* $2^{2^{m-2}}$.

(iv) Let $\mathbf{s}^{(m)}$ *be an antisymmetric string satisfying* $\varphi_m(\mathbf{s}^{(m)}) = 0, 0, \ldots, 0$. *Then either* $s_0, s_1, \ldots, s_{2^{m-1}-1}$ *is itself antisymmetric, or the string*

$$s_0, s_1, \ldots, s_{2^{m-2}} + 1, \ldots, s_{2^{m-1}-1}$$

is antisymmetric.
In the first case $\varphi_{m-1}(s_0, s_1, \ldots, s_{2^{m-1}-1}) = t_0, t_1, \ldots, t_{2^{m-2}-1}$ *is antisymmetric, and in the second case the string* $t_0 - 1, t_1, \ldots, t_{2^{m-2}-1}$ *is antisymmetric.*

Theorem 1. *For* $n = 2^m$, *let* $\mathcal{N}_m(s)$ *denote the number of strings*

$$(a_1, a_2, \ldots, a_{(n/2)-1}) \in \mathbb{F}_2^{(n/2)-1}$$

for which the quadratic function f *from* $\mathbb{F}_{2^n}$ *to* $\mathbb{F}_2$, *given by*

$$f(x) = \mathrm{Tr_n}\left(\sum_{i=1}^{(n/2)-1} a_i x^{2^i+1}\right)$$

is s*-plateaued. Then*

$$\mathcal{N}_m(s) = \begin{cases} 2^{2^{m-1}-1-k} & : \quad s = 2k, k = 1, \ldots, 2^{m-1}-1, \\ 0 & : \quad s = 0 \text{ or } s \text{ odd.} \end{cases}$$

Proof. We use induction. One can easily see that the assertion holds for small m. Now suppose that $\mathcal{N}_{m-1}(s) = 2^{2^{m-2}-1-k}$ for $s = 2k, k = 1, \ldots, 2^{m-2}-1$, i.e., for these values of s, there are $2^{2^{m-2}-1-k}$ sequences, which are 2^{m-1}-periodic with linear complexity $2^{m-1} - s$, corresponding to antisymmetric strings. By Proposition 1 (iii), for each of these stings we have $2^{2^{m-2}}$ antisymmetric preimages giving rise to antisymmetric 2^m-periodic sequences with linear complexity $2^m - s$. Proposition 1 (ii) implies that these are all such sequences. Consequently, we get $\mathcal{N}_m(s) = 2^{2^{m-2}} 2^{2^{m-2}-1-k} = 2^{2^{m-1}-1-k}$ when $s = 2k, k = 1, \ldots, 2^{m-2}-1$. It remains to show that the formula holds for $s = 2k$ with $k = 2^{m-2}, \ldots, 2^{m-1}-1$. We therefore have to enumerate the antisymmetric 2^m-periodic sequences with a given linear complexity $2^m - s \leq 2^{m-1}$. First observe that these are the sequences corresponding to antisymmetric strings $\mathbf{s}^{(m)} = s_0, \ldots, s_{2^m-1}$ such that
(a) $\varphi_m(\mathbf{s}^{(m)}) = 0, 0, \ldots, 0$, or
(b) the sequence corresponding to $s_0, \ldots, s_{2^{m-1}-1}$ has linear complexity $2^m - s$.
By Proposition 1 (iv), (a) implies that $s_0, \ldots, s_{2^{m-1}-1}$ or $s_0, s_1, \ldots, s_{2^{m-2}} +$

$1, \ldots, s_{2^{m-1}-1}$ is antisymmetric. Moreover it is easily seen that for any such string there is exactly one corresponding antisymmetric string $\mathbf{s}^{(m)}$ for which (a) holds. Having an odd number of 1's, the $2^{m-2}-1$ strings of the second type yield 2^{m-1}-periodic sequences with linear complexity $L = 2^{m-1}$ (thus $s = 2^m - L = 2^{m-1}$). Among the $2^{m-2}-1$ strings of the first type, by our hypothesis, precisely $2^{2^{m-2}-1-\kappa}$ yield 2^{m-1}-periodic sequences with linear complexity $L = 2^{m-1} - 2\kappa$, $\kappa = 1, \ldots, 2^{m-2}-1$. Substituting κ by $k - 2^{m-2}$ we obtain $2^{2^{m-1}-1-k}$ for the number of antisymmetric 2^m-periodic sequences with linear complexity $L = 2^m - 2k$ (thus $s = 2k$) for $k = 2^{m-2}+1, \ldots, 2^{m-1}-1$, hence $\mathcal{N}_m(s) = 2^{2^{m-2}} 2^{2^{m-2}-1-k} = 2^{2^{m-1}-1-k}$ for these values of k, and $s = 2k$. Note that from the above arguments we also see that $\mathcal{N}_m(s) = 0$ when $s = 0$ and when s is odd. However one can also see directly that $\mathcal{N}_m(0) = 0$ since antisymmetric strings contain an even number of 1's, and the statement for odd s simply follows from the Fourier transform being an integer. □

Note that the arguments in the proof also enable the construction of s-plateaued quadratic functions from $\mathbb{F}_{2^{2^m}}$ to $\mathbb{F}_2$ for a prescribed value of s.

2.2 The case $n = p_1 p_2 \cdots p_r$

The results in this subsection are obtained with a different approach, namely by analysing the factorization of $x^n + 1$ into self-reciprocal polynomials. With the observation that $\gcd(x^n+1, A(x))$ is again self-reciprocal if $A(x)$ is self-reciprocal, one obtains the following general theorem, which is valid for arbitrary integers n.

Theorem 2. *Let n be arbitrary.*

(i) If n is odd, then there exists an s-plateaued function of the form (1) *if and only if s is odd and $x^n + 1$ has a self-reciprocal factor $h(x)$ of degree s* (*in which case $x^n + 1$ is always divisible by $x + 1$*).

(ii) If n is even then there exists an s-plateaued function of the form (1) *if and only if s is even and $x^n + 1$ has a self-reciprocal factor $h(x)$ of degree s divisible by $(x + 1)^2$.*

Note that if $n = 2^v n_1$, n_1 odd, then $x^n + 1 = (x^{n_1} + 1)^{2^v}$. Thus it is sufficient to analyse the factorization of $x^n + 1$ for odd n. Here we only consider the case of n being square-free. Our main tool for studying the factorization of $x^n + 1$ into self-reciprocals is, as expected, the use of cyclotomic cosets modulo n relative to powers of 2.

We denote the n-th cyclotomic polynomial by $\mathcal{Q}_n$, and denote the 2-adic valuation of an integer k by $\nu(k)$, i.e., $2^{\nu(k)}$ is the largest power of 2 which divides k. The following lemma describes for which squarefree integers $n = p_1 p_2 \cdots p_r$ the irreducible factors of $\mathcal{Q}_n$ are self-reciprocal. Note that $\mathcal{Q}_n$ has d irreducible factors where $d = \mathrm{lcm}(d_1, \ldots, d_r) = ord_n 2$.

Lemma 1. *Let $n = p_1 p_2 \cdots p_r$, $d_i = ord_{p_i}2$ and $d = ord_n 2$. Suppose the irreducible factors of $\mathcal{Q}_n$ are $f_1, \ldots, f_{\varphi(n)/d}$. Then*

(i) The polynomials $f_1, \ldots, f_{\varphi(n)/d}$ are self-reciprocal if and only if $\nu(d_1) = \nu(d_2) = \cdots = \nu(d_r) > 0$. In particular, if n is a prime p, then $f_1, \ldots, f_{(p-1)/d}$ are self-reciprocal if and only if d is even.

(ii) If $\nu(d_i) \neq \nu(d_j)$ for some $1 \leq i, j \leq \varphi(n)/d$, then none of the polynomials f_t, $1 \leq t \leq \varphi(n)/d$, is self-reciprocal, and for each t, $1 \leq t \leq \varphi(n)/d$, there exists a unique $t' \neq t$, $1 \leq t' \leq \varphi(n)/d$ such that the product $f_t f_{t'}$ is self-reciprocal.

Idea of Proof. First observe that the irreducible factors of $\mathcal{Q}_n$ are self-reciprocal if every cyclotomic coset modulo n relative to powers of 2 containing the element a also contains the element $-a$. Therefore an irreducible factor of $\mathcal{Q}_n$ is self-reciprocal if the cyclotomic coset of 1 also contains -1, i.e., $2^k \equiv -1 \bmod n$ for some integer k. This is equivalent to $2^k \equiv -1 \bmod p_1$, $i \leq i \leq r$, which holds if and only if d_i divides $2k$ but not k for each i. This leads to the condition $\nu(d_1) = \nu(d_2) = \cdots = \nu(d_r) > 0$. □

By Lemma 1 and [7, Exercise 3.15] the polynomial $x^n + 1$ factors into self-reciprocal irreducible polynomials if and only $\nu(d_1) = \nu(d_2) = \cdots = \nu(d_r) > 0$.

Example 2. I. $n = 5 \cdot 13 = 65$, then $d_1 = 4, d_2 = 12$, hence $\nu(d_1) = \nu(d_2)$. Consequently $x^{65} + 1$ factors into self-reciprocal irreducible polynomials.

II. $n = 3 \cdot 5 \cdot 7 = 105$, then $d_1 = 2, d_2 = 4, d_3 = 3$ and $\nu(d_1) \neq \nu(d_2)$. Hence not all the irreducible factors of $x^{105} + 1$ are self-reciprocal.

A simple consequence of the above lemma is also the main result of [5]: All functions of the form (1) from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$ are 1-plateaued (near-bent) only when $n = p$ is a prime, satisfying $p \equiv 3 \bmod 4$ with $ord_p 2 = (p-1)/2$, or 2 is a primitive root modulo p. Note that the self-reciprocal factors of $x^n + 1$ are exactly $x + 1$ and $1 + x \cdots + x^{n-1}$ only for such n.

In order to determine the possible values of s that a function of the form (1) has Fourier spectrum $\mathcal{F}_{s,f}$, we consider all cyclotomic polynomials $\mathcal{Q}_m$, $m|n$ and apply Lemma 1 accordingly:

Example 2.II. continued: $n = 3 \cdot 5 \cdot 7 = 105, d_1 = 2, d_2 = 4, d_3 = 3$.
$\varphi(n) = 48$, $d = \gcd(2,4,3) = 12$, and $\nu(d_1) \neq \nu(d_2)$. Hence $x^{105} + 1$ has 2 self-reciprocal factors of degree 24.
$\varphi(35) = 24$, $\gcd(d_2, d_3) = \gcd(4,3) = 12$, and $\nu(4) \neq \nu(3)$, which yields 2 cyclotomic classes of cardinality 12, and hence one self-reciprocal factor of degree 24.
$\varphi(21) = 12$, $\gcd(2,3) = 6$. There are 2 cyclotomic classes of cardinality 6 corresponding to one self-reciprocal factor of degree 12.
$\varphi(15) = 8$, $\gcd(2,4) = 4$, $\nu(2) \neq \nu(4)$. There are 2 cyclotomic classes of cardinality 4, giving one self-reciprocal factor of degree 8.
Similarly it is easy to see that $x^{105} + 1$ has one self-reciprocal factor of degree 6, and two irreducible self-reciprocal factors; one of degree 4, and one of degree 2.

Therefore s can be any integer less than 105 of the form $s = 24k_1 + 12k_2 + 8k_3 + 6k_4 + 4k_5 + 2k_6 + 1$, $0 \leq k_1 \leq 3$ and $0 \leq k_i \leq 1$ for $2 \leq i \leq 6$.

We list the possible values of s in two special cases:

Corollary 1. *Let n be an odd prime with $ord_n 2 = d$.*

(i) If d is even, then there exists an s-plateaued function of the form (1) *from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$ if and only if $s = kd + 1$ for some $0 \leq k \leq (n-1)/d - 1$.*

(ii) If d is odd, then there exists an s-plateaued function of the form (1) *from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$ if and only if $s = 2kd + 1$ for some $0 \leq k \leq (n-1)/(2d) - 1$.*

Corollary 2. *Let $n = pq$ for two odd primes p and q and let $ord_p 2 = d_p$, $ord_q 2 = d_q$. The integers s for which there exists an s-plateaued function of the form* (1) *from $\mathbb{F}_2^n$ to $\mathbb{F}_2$ are given as follows: $s < n$ and*

1. *if $\nu(d_p) = \nu(d_q) > 0$, then $s = k_1 \mathrm{lcm}(d_p, d_q) + k_2 d_p + k_3 d_q$, $0 \leq k_1 \leq (p-1)(q-1)/\mathrm{lcm}(d_p, d_q)$, $0 \leq k_2 \leq (p-1)/d_p$, $0 \leq k_3 \leq (q-1)/d_q$;*
2. *if $\nu(d_p) > 0, \nu(d_q) > 0$ and $\nu(d_p) \neq \nu(d_q) > 0$, then $s = 2k_1 \mathrm{lcm}(d_p, d_q) + k_2 d_p + k_3 d_q$, $0 \leq k_1 \leq (p-1)(q-1)/(2\mathrm{lcm}(d_p, d_q))$, $0 \leq k_2 \leq (p-1)/d_p$, $0 \leq k_3 \leq (q-1)/d_q$;*
3. *if $\nu(d_p) > 0, \nu(d_q) = 0$, then $s = 2k_1 \mathrm{lcm}(d_p, d_q) + k_2 d_p + 2k_3 d_q$, $0 \leq k_1 \leq (p-1)(q-1)/(2\mathrm{lcm}(d_p, d_q))$, $0 \leq k_2 \leq (p-1)/d_p$, $0 \leq k_3 \leq (q-1)/(2d_q)$;*
4. *$\nu(d_p) = \nu(d_q) = 0$, then $s = 2k_1 \mathrm{lcm}(d_p, d_q) + 2k_2 d_p + 2k_3 d_q$, $0 \leq k_1 \leq (p-1)(q-1)/(2\mathrm{lcm}(d_p, d_q))$, $0 \leq k_2 \leq (p-1)/(2d_p)$, $0 \leq k_3 \leq (q-1)/(2d_q)$.*

Now the methods of constructing s-plateaued functions of the form (1) with prescribed s are obvious:

1. Among the self-reciprocal factors of $x^n + 1$ select some, whose degrees add up to s and form their product $h(x)$. We remark that s must be odd if n is odd, thus $x + 1$ must divide $h(x)$. If n is even then also s must be even, hence $h(x)$ will always be divisible by $(x+1)^g$ for some even integer $g \geq 2$.

2. Multiply $h(x)$ with a self-reciprocal polynomial of even degree, which is relatively prime to $(x^n + 1)/h(x)$. The resulting product $g(x)$ must be of degree at most $n - 1$.

3. Multiply $g(x)$ with x^{i_0}, where i_0 is the unique integer such that $A(x) = x^{i_0} g(x)$ is of the form (2). Note that $a_0 = 0$ for any $A(x)$, obtained this way.

4. The polynomial $f(x)$ of the form (1) corresponding to a $A(x)$ is then s-plateaued. Note that a_0 can be chosen as 0 or 1.

The following example leads to an easy proof of a result of [2].

Example 3. Construction of s-plateaued functions with maximal possible value for s:

As $n+s$ must be even, the maximal possible value for s is $s = n-2$. We have to choose a self-reciprocal divisor $h(x)$ of x^n+1 of degree $n-2$. The only possible choices for $h(x)$ are
(i) $h(x) = (x^n+1)/(x+1)^2$.
(ii) $h(x) = (x^n+1)/(x^2+x+1)$.
Now (i) implies that n is even and since then $(x+1)^2$ must divide $h(x)$, we need $4|n$, and (ii) implies that $3|n$. The step 2 in the above procedure can not be carried out, thus $g(x) = h(x)$, and $i_0 = 1$. We then get

$$A(x) = xh(x) = x + x^3 + x^5 + \cdots + x^{n-1} \quad \text{in case (i), and}$$
$$A(x) = xh(x) = x + x^2 + x^4 + x^5 + x^7 + x^8 + \cdots + x^{n-2} + x^{n-1} \quad \text{in case (ii).}$$

The following corollary easily follows from the argument used in the above example.

Corollary 3. *The quadratic function f of the form* (1) *is* $(n-2)$*-plateaued if and only if*

(i) $4|n$ *and* $f(x) = \mathrm{Tr_n}\left(\varepsilon x^2 + x^{2+1} + x^{2^3+1} + x^{2^5+1} + \cdots + x^{2^{n/2-1}+1}\right)$, $\varepsilon \in \{0,1\}$, *or*

(ii) $3|n$ *and* $f(x) = \mathrm{Tr_n}\left(\varepsilon x^2 + \sum_{i=1, i\not\equiv 0 \bmod 3}^{\lfloor n-1/2 \rfloor} x^{2^i+1}\right)$, $\varepsilon \in \{0,1\}$.

Compare our Corollary 3 with Theorem 2.4 in [2].

3 Conclusion

We enumerate quadratic s-plateaued functions from $\mathbb{F}_{2^{2m}}$ to $\mathbb{F}_2$, given by (1). For squarefree integers $n = p_1 p_2 \cdots p_r$ we characterize the integers s, for which s-plateaued functions from $\mathbb{F}_{2^n}$ to $\mathbb{F}_2$ of the form (1) exist. Methods for constructing such functions are also described. Our results generalize earlier work on the case $s = 1$, see [4, 5].

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