

LinksPlatform's Platform.Numbers Class Library

1.1 ./csharp/Platform.Numbers/Arithmetic.cs

```
1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Numbers
6 {
7     /// <summary>
8     /// <para>Represents a set of arithmetic methods.</para>
9     /// <para>Представляет набор арифметических методов.</para>
10    /// </summary>
11    public static class Arithmetic
12    {
13        /// <summary>
14        /// <para>Performing adding the x and y arguments.</para>
15        /// <para>Выполняет сложение аргументов x и y.</para>
16        /// </summary>
17        /// <typeparam name="T">
18        /// <para>Numbers type.</para>
19        /// <para>Тип чисел.</para>
20        /// </typeparam>
21        /// <param name="x">
22        /// <para>The first term.</para>
23        /// <para>Первое слагаемое.</para>
24        /// </param>
25        /// <param name="y">
26        /// <para>The second term.</para>
27        /// <para>Второе слагаемое.</para>
28        /// </param>
29        /// <returns>
30        /// <para>Sum of x and y.</para>
31        /// <para>Сумма x и y.</para>
32        /// </returns>
33        [MethodImpl(MethodImplOptions.AggressiveInlining)]
34        public static T Add<T>(T x, T y) => Arithmetic<T>.Add(x, y);
35
36        /// <summary>
37        /// <para>Performs subtracting y from x.</para>
38        /// <para>Выполняет вычитание y из x.</para>
39        /// </summary>
40        /// <typeparam name="T">
41        /// <para>Numbers type.</para>
42        /// <para>Тип чисел.</para>
43        /// </typeparam>
44        /// <param name="x">
45        /// <para>Minuend.</para>
46        /// <para>Уменьшаемое.</para>
47        /// </param>
48        /// <param name="y">
49        /// <para>Subtrahend.</para>
50        /// <para>Вычитаемое.</para>
51        /// </param>
52        /// <returns>
53        /// <para>Difference between x and y.</para>
54        /// <para>Разность между x и y.</para>
55        /// </returns>
56        [MethodImpl(MethodImplOptions.AggressiveInlining)]
57        public static T Subtract<T>(T x, T y) => Arithmetic<T>.Subtract(x, y);
58
59        /// <summary>
60        /// <para>Performs multiplication x by y.</para>
61        /// <para>Выполняет умножение x на y.</para>
62        /// </summary>
63        /// <typeparam name="T">
64        /// <para>Numbers type.</para>
65        /// <para>Тип чисел.</para>
66        /// </typeparam>
67        /// <param name="x">
68        /// <para>First multiplier.</para>
69        /// <para>Первый множитель.</para>
70        /// </param>
71        /// <param name="y">
72        /// <para>Second multiplier.</para>
73        /// <para>Второй множитель.</para>
74        /// </param>
75        /// <returns>
76        /// <para>Product of x and y.</para>
```

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77     /// <para>Произведение x и y.</para>
78     /// </returns>
79     [MethodImpl(MethodImplOptions.AggressiveInlining)]
80     public static T Multiply<T>(T x, T y) => Arithmetic<T>.Multiply(x, y);
81
82     /// <summary>
83     /// <para>Performs dividing x by y.</para>
84     /// <para>Выполняет деление x на y.</para>
85     /// </summary>
86     /// <typeparam name="T">
87     /// <para>Numbers type.</para>
88     /// <para>Тип чисел.</para>
89     /// </typeparam>
90     /// <param name="x">
91     /// <para>Dividend.</para>
92     /// <para>Делимое.</para>
93     /// </param>
94     /// <param name="y">
95     /// <para>Divider.</para>
96     /// <para>Делитель.</para>
97     /// </param>
98     /// <returns>
99     /// <para>Quoitent of x and y.</para>
100    /// <para>Частное x и y.</para>
101    /// </returns>
102    [MethodImpl(MethodImplOptions.AggressiveInlining)]
103    public static T Divide<T>(T x, T y) => Arithmetic<T>.Divide(x, y);
104
105    /// <summary>
106    /// <para>Increasing the number x by one.</para>
107    /// <para>Увеличивает число x на единицу.</para>
108    /// </summary>
109    /// <typeparam name="T">
110    /// <para>Number type.</para>
111    /// <para>Тип числа.</para>
112    /// </typeparam>
113    /// <param name="x">
114    /// <para>The number to increase.</para>
115    /// <para>Число для увеличения.</para>
116    /// </param>
117    /// <returns>
118    /// <para>Increase by one number x.</para>
119    /// <para>Увеличенное на единицу число x.</para>
120    /// </returns>
121    [MethodImpl(MethodImplOptions.AggressiveInlining)]
122    public static T Increment<T>(T x) => Arithmetic<T>.Increment(x);
123
124    /// <summary>
125    /// <para>Increases the value of argument x by one.</para>
126    /// <para>Увеличивает значение аргумента x на единицу.</para>
127    /// </summary>
128    /// <typeparam name="T">
129    /// <para>Number type.</para>
130    /// <para>Тип числа.</para>
131    /// </typeparam>
132    /// <param name="x">
133    /// <para>The argument to increase.</para>
134    /// <para>Аргумент для увеличения.</para>
135    /// </param>
136    /// <returns>
137    /// <para>Increased argument x value.</para>
138    /// <para>Увеличенное значение аргумента x.</para>
139    /// </returns>
140    [MethodImpl(MethodImplOptions.AggressiveInlining)]
141    public static T Increment<T>(ref T x) => x = Arithmetic<T>.Increment(x);
142
143    /// <summary>
144    /// <para>Decrease number x by one.</para>
145    /// <para>Уменьшает число x на единицу.</para>
146    /// </summary>
147    /// <typeparam name="T">
148    /// <para>Number type.</para>
149    /// <para>Тип числа.</para>
150    /// </typeparam>
151    /// <param name="x">
152    /// <para>The number to reduce.</para>
153    /// <para>Число для уменьшения.</para>
154    /// </param>

```

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155     /// <returns>
156     /// <para>Decreased by one number x.</para>
157     /// <para>Уменьшенное на единицу число x.</para>
158     /// </returns>
159     [MethodImpl(MethodImplOptions.AggressiveInlining)]
160     public static T Decrement<T>(T x) => Arithmetic<T>.Decrement(x);
161
162     /// <summary>
163     /// <para>Decreases the value of the argument x by one.</para>
164     /// <para>Уменьшает значение аргумента x на единицу.</para>
165     /// </summary>
166     /// <typeparam name="T">
167     /// <para>Number type.</para>
168     /// <para>Тип числа.</para>
169     /// </typeparam>
170     /// <param name="x">
171     /// <para>The argument to reduce.</para>
172     /// <para>Аргумент для уменьшения.</para>
173     /// </param>
174     /// <returns>
175     /// <para>Decreased argument x value.</para>
176     /// <para>Уменьшенное значение аргумента x.</para>
177     /// </returns>
178     [MethodImpl(MethodImplOptions.AggressiveInlining)]
179     public static T Decrement<T>(ref T x) => x = Arithmetic<T>.Decrement(x);
180 }
181 }

```

1.2 ./csharp/Platform.Numbers/ArithmeticExtensions.cs

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Numbers
6 {
7     public static class ArithmeticExtensions
8     {
9         [MethodImpl(MethodImplOptions.AggressiveInlining)]
10        public static T Decrement<T>(this ref T x) where T : struct => x =
11            ↪ Arithmetic<T>.Decrement(x);
12
13        [MethodImpl(MethodImplOptions.AggressiveInlining)]
14        public static T Increment<T>(this ref T x) where T : struct => x =
15            ↪ Arithmetic<T>.Increment(x);
16    }
17 }

```

1.3 ./csharp/Platform.Numbers/Arithmetic[T].cs

```

1 using System;
2 using System.Reflection.Emit;
3 using System.Runtime.CompilerServices;
4 using Platform.Exceptions;
5 using Platform.Reflection;
6
7 // ReSharper disable StaticFieldInGenericType
8 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Numbers
11 {
12     public static class Arithmetic<T>
13     {
14         public static readonly Func<T, T, T> Add = CompileAddDelegate();
15         public static readonly Func<T, T, T> Subtract = CompileSubtractDelegate();
16         public static readonly Func<T, T, T> Multiply = CompileMultiplyDelegate();
17         public static readonly Func<T, T, T> Divide = CompileDivideDelegate();
18         public static readonly Func<T, T> Increment = CompileIncrementDelegate();
19         public static readonly Func<T, T> Decrement = CompileDecrementDelegate();
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         private static Func<T, T, T> CompileAddDelegate()
23         {
24             return DelegateHelpers.Compile<Func<T, T, T>>(emitter =>
25             {
26                 Ensure.Always.IsNumeric<T>();
27                 emitter.LoadArguments(0, 1);
28                 emitter.Add();
29                 emitter.Return();
30             });
31         }
32     }
33 }

```

```

32 [MethodImpl(MethodImplOptions.AggressiveInlining)]
33 private static Func<T, T, T> CompileSubtractDelegate()
34 {
35     return DelegateHelpers.Compile<Func<T, T, T>>(emitter =>
36     {
37         Ensure.Always.IsNumeric<T>();
38         emitter.LoadArguments(0, 1);
39         emitter.Subtract();
40         emitter.Return();
41     });
42 }
43
44 [MethodImpl(MethodImplOptions.AggressiveInlining)]
45 private static Func<T, T, T> CompileMultiplyDelegate()
46 {
47     return DelegateHelpers.Compile<Func<T, T, T>>(emitter =>
48     {
49         Ensure.Always.IsNumeric<T>();
50         emitter.LoadArguments(0, 1);
51         emitter.Emit(OpCodes.Mul);
52         emitter.Return();
53     });
54 }
55
56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 private static Func<T, T, T> CompileDivideDelegate()
58 {
59     return DelegateHelpers.Compile<Func<T, T, T>>(emitter =>
60     {
61         Ensure.Always.IsNumeric<T>();
62         emitter.LoadArguments(0, 1);
63         if(NumericType<T>.IsSigned)
64         {
65             emitter.Emit(OpCodes.Div);
66         }
67         else
68         {
69             emitter.Emit(OpCodes.Div_Un);
70         }
71         emitter.Return();
72     });
73 }
74
75 [MethodImpl(MethodImplOptions.AggressiveInlining)]
76 private static Func<T, T> CompileIncrementDelegate()
77 {
78     return DelegateHelpers.Compile<Func<T, T>>(emitter =>
79     {
80         Ensure.Always.IsNumeric<T>();
81         emitter.LoadArgument(0);
82         emitter.Increment<T>();
83         emitter.Return();
84     });
85 }
86
87 [MethodImpl(MethodImplOptions.AggressiveInlining)]
88 private static Func<T, T> CompileDecrementDelegate()
89 {
90     return DelegateHelpers.Compile<Func<T, T>>(emitter =>
91     {
92         Ensure.Always.IsNumeric<T>();
93         emitter.LoadArgument(0);
94         emitter.Decrement<T>();
95         emitter.Return();
96     });
97 }
98 }
99 }
100 }

```

1.4 ./csharp/Platform.Numbers/Bit.cs

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5
6 namespace Platform.Numbers
7 {
8

```

```

9  /// <summary>
10 /// <para>A set of operations on the set bits of a number.</para>
11 /// <para>Набор операций над установленными битами числа.</para>
12 /// </summary>
13
14 public static class Bit
15 {
16     /// <summary>
17     /// <para>Counts the number of bits set in a number.</para>
18     /// <para>Подсчитывает количество установленных бит в числе.</para>
19     /// </summary>
20     /// <param>
21     /// <para>Bitwise number.</para>
22     /// <para>Число в битовом представлении.</para>
23     /// </param>
24     /// <returns>
25     /// <para>Number of bits set in a number.</para>
26     /// <para>Количество установленных бит в числе.</para>
27     /// </returns>
28     [MethodImpl(MethodImplOptions.AggressiveInlining)]
29     public static long Count(long x)
30     {
31         long n = 0;
32         while (x != 0)
33         {
34             n++;
35             x &= x - 1;
36         }
37         return n;
38     }
39     /// <summary>
40     /// <para>Searches for the first bit set in a number.</para>
41     /// <para>Ищет первый установленный бит в числе.</para>
42     /// </summary>
43     /// <param>
44     /// <para>Bitwise number.</para>
45     /// <para>Число в битовом представлении.</para>
46     /// </param>
47     /// <returns>
48     /// <para>First bit set.</para>
49     /// <para>Первый установленный бит.</para>
50     /// </returns>
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     public static int GetLowestPosition(ulong value)
53     {
54         if (value == 0)
55         {
56             return -1;
57         }
58         var position = 0;
59         while ((value & 1UL) == 0)
60         {
61             value >>= 1;
62             ++position;
63         }
64         return position;
65     }
66
67     /// <summary>
68     /// <para>.</para>
69     /// <para>.</para>
70     /// </summary>
71     /// <returns>
72     /// <para>.</para>
73     /// <para>.</para>
74     /// </returns>
75     [MethodImpl(MethodImplOptions.AggressiveInlining)]
76     public static T Not<T>(T x) => Bit<T>.Not(x);
77
78     /// <summary>
79     /// <para>.</para>
80     /// <para>.</para>
81     /// </summary>
82     /// <returns>
83     /// <para>.</para>
84     /// <para>.</para>
85     /// </returns>
86     [MethodImpl(MethodImplOptions.AggressiveInlining)]
87     public static T Or<T>(T x, T y) => Bit<T>.Or(x, y);

```

```

88
89     /// <summary>
90     /// <para>.</para>
91     /// <para>.</para>
92     /// </summary>
93     /// <returns>
94     /// <para>.</para>
95     /// <para>.</para>
96     /// </returns>
97     [MethodImpl(MethodImplOptions.AggressiveInlining)]
98     public static T And<T>(T x, T y) => Bit<T>.And(x, y);
99
100    /// <summary>
101    /// <para>.</para>
102    /// <para>.</para>
103    /// </summary>
104    /// <returns>
105    /// <para>.</para>
106    /// <para>.</para>
107    /// </returns>
108    [MethodImpl(MethodImplOptions.AggressiveInlining)]
109    public static T ShiftLeft<T>(T x, int y) => Bit<T>.ShiftLeft(x, y);
110
111    /// <summary>
112    /// <para>.</para>
113    /// <para>.</para>
114    /// </summary>
115    /// <returns>
116    /// <para>.</para>
117    /// <para>.</para>
118    /// </returns>
119    [MethodImpl(MethodImplOptions.AggressiveInlining)]
120    public static T ShiftRight<T>(T x, int y) => Bit<T>.ShiftRight(x, y);
121
122    /// <summary>
123    /// <para>.</para>
124    /// <para>.</para>
125    /// </summary>
126    /// <returns>
127    /// <para>.</para>
128    /// <para>.</para>
129    /// </returns>
130    [MethodImpl(MethodImplOptions.AggressiveInlining)]
131    public static T PartialWrite<T>(T target, T source, int shift, int limit) =>
132        ↪ Bit<T>.PartialWrite(target, source, shift, limit);
133
134    /// <summary>
135    /// <para>.</para>
136    /// <para>.</para>
137    /// </summary>
138    /// <returns>
139    /// <para>.</para>
140    /// <para>.</para>
141    /// </returns>
142    [MethodImpl(MethodImplOptions.AggressiveInlining)]
143    public static T PartialRead<T>(T target, int shift, int limit) =>
144        ↪ Bit<T>.PartialRead(target, shift, limit);
145    }
146 }

```

1.5 ./csharp/Platform.Numbers/BitExtensions.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Numbers
6  {
7      /// <summary>
8      /// <returns> bit operations </returns>
9      /// </summary>
10     /* bit operations */
11     public static class BitwiseExtensions
12     {
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public static T Not<T>(this ref T target) where T : struct => target = Bit.Not(target);
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18

```



```

69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 private static Func<T, int, T> CompileShiftRightDelegate()
71 {
72     return DelegateHelpers.Compile<Func<T, int, T>>(emitter =>
73     {
74         Ensure.Always.IsNumeric<T>();
75         emitter.LoadArguments(0, 1);
76         emitter.ShiftRight();
77         emitter.Return();
78     });
79 }
80
81 [MethodImpl(MethodImplOptions.AggressiveInlining)]
82 private static Func<T, T, int, int, T> CompilePartialWriteDelegate()
83 {
84     return DelegateHelpers.Compile<Func<T, T, int, int, T>>(emitter =>
85     {
86         Ensure.Always.IsNumeric<T>();
87         var constants = GetConstants();
88         var bitsNumber = constants.Item1;
89         var numberFilledWithOnes = constants.Item2;
90         ushort shiftArgument = 2;
91         ushort limitArgument = 3;
92         var checkLimit = emitter.DefineLabel();
93         var calculateSourceMask = emitter.DefineLabel();
94         // Check shift
95         emitter.LoadArgument(shiftArgument);
96         emitter.LoadConstant(0);
97         emitter.BranchIfGreaterOrEqual(checkLimit); // Skip fix
98         // Fix shift
99         emitter.LoadConstant(bitsNumber);
100        emitter.LoadArgument(shiftArgument);
101        emitter.Add();
102        emitter.StoreArgument(shiftArgument);
103        emitter.MarkLabel(checkLimit);
104        // Check limit
105        emitter.LoadArgument(limitArgument);
106        emitter.LoadConstant(0);
107        emitter.BranchIfGreaterOrEqual(calculateSourceMask); // Skip fix
108        // Fix limit
109        emitter.LoadConstant(bitsNumber);
110        emitter.LoadArgument(limitArgument);
111        emitter.Add();
112        emitter.StoreArgument(limitArgument);
113        emitter.MarkLabel(calculateSourceMask);
114        var sourceMask = emitter.DeclareLocal<T>();
115        var targetMask = emitter.DeclareLocal<T>();
116        emitter.LoadConstant(typeof(T), numberFilledWithOnes);
117        emitter.LoadArgument(limitArgument);
118        emitter.ShiftLeft();
119        emitter.Not();
120        emitter.LoadConstant(typeof(T), numberFilledWithOnes);
121        emitter.And();
122        emitter.StoreLocal(sourceMask);
123        emitter.LoadLocal(sourceMask);
124        emitter.LoadArgument(shiftArgument);
125        emitter.ShiftLeft();
126        emitter.Not();
127        emitter.StoreLocal(targetMask);
128        emitter.LoadArgument(0); // target
129        emitter.LoadLocal(targetMask);
130        emitter.And();
131        emitter.LoadArgument(1); // source
132        emitter.LoadLocal(sourceMask);
133        emitter.And();
134        emitter.LoadArgument(shiftArgument);
135        emitter.ShiftLeft();
136        emitter.Or();
137        emitter.Return();
138    });
139 }
140
141 [MethodImpl(MethodImplOptions.AggressiveInlining)]
142 private static Func<T, int, int, T> CompilePartialReadDelegate()
143 {
144     return DelegateHelpers.Compile<Func<T, int, int, T>>(emitter =>
145     {
146         Ensure.Always.IsNumeric<T>();

```



```

147     var constants = GetConstants();
148     var bitsNumber = constants.Item1;
149     var numberFilledWithOnes = constants.Item2;
150     ushort shiftArgument = 1;
151     ushort limitArgument = 2;
152     var checkLimit = emitter.DefineLabel();
153     var calculateSourceMask = emitter.DefineLabel();
154     // Check shift
155     emitter.LoadArgument(shiftArgument);
156     emitter.LoadConstant(0);
157     emitter.BranchIfGreaterOrEqual(checkLimit); // Skip fix
158     // Fix shift
159     emitter.LoadConstant(bitsNumber);
160     emitter.LoadArgument(shiftArgument);
161     emitter.Add();
162     emitter.StoreArgument(shiftArgument);
163     emitter.MarkLabel(checkLimit);
164     // Check limit
165     emitter.LoadArgument(limitArgument);
166     emitter.LoadConstant(0);
167     emitter.BranchIfGreaterOrEqual(calculateSourceMask); // Skip fix
168     // Fix limit
169     emitter.LoadConstant(bitsNumber);
170     emitter.LoadArgument(limitArgument);
171     emitter.Add();
172     emitter.StoreArgument(limitArgument);
173     emitter.MarkLabel(calculateSourceMask);
174     var sourceMask = emitter.DeclareLocal<T>();
175     var targetMask = emitter.DeclareLocal<T>();
176     emitter.LoadConstant(typeof(T), numberFilledWithOnes);
177     emitter.LoadArgument(limitArgument); // limit
178     emitter.ShiftLeft();
179     emitter.Not();
180     emitter.LoadConstant(typeof(T), numberFilledWithOnes);
181     emitter.And();
182     emitter.StoreLocal(sourceMask);
183     emitter.LoadLocal(sourceMask);
184     emitter.LoadArgument(shiftArgument);
185     emitter.ShiftLeft();
186     emitter.StoreLocal(targetMask);
187     emitter.LoadArgument(0); // target
188     emitter.LoadLocal(targetMask);
189     emitter.And();
190     emitter.LoadArgument(shiftArgument);
191     emitter.ShiftRight();
192     emitter.Return();
193     });
194 }
195
196 [MethodImpl(MethodImplOptions.AggressiveInlining)]
197 private static Tuple<int, T> GetConstants()
198 {
199     var type = typeof(T);
200     if (type == typeof(ulong))
201     {
202         return new Tuple<int, T>(64, (T)(object)ulong.MaxValue);
203     }
204     if (type == typeof(uint))
205     {
206         return new Tuple<int, T>(32, (T)(object)uint.MaxValue);
207     }
208     if (type == typeof(ushort))
209     {
210         return new Tuple<int, T>(16, (T)(object)ushort.MaxValue);
211     }
212     if (type == typeof(byte))
213     {
214         return new Tuple<int, T>(8, (T)(object)byte.MaxValue);
215     }
216     throw new NotSupportedException();
217 }
218 }
219 }

```

1.7 ./csharp/Platform.Numbers/Math.cs

```

1 using System;
2 using System.Runtime.CompilerServices;
3

```

```

4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Numbers
7 {
8     /// <remarks>
9     /// Resizable array (FileMappedMemory) for values cache may be used. or cached oeis.org
10    /// </remarks>
11    public static class Math
12    {
13        /// <remarks>
14        /// <para>Source: https://oeis.org/A000142/list </para>
15        /// <para>Источник: https://oeis.org/A000142/list </para>
16        /// </remarks>
17
18        private static readonly ulong[] _factorials =
19        {
20            1, 1, 2, 6, 24, 120, 720, 5040, 40320, 362880, 3628800, 39916800,
21            479001600, 6227020800, 87178291200, 1307674368000, 20922789888000,
22            355687428096000, 6402373705728000, 121645100408832000, 2432902008176640000
23        };
24
25        /// <remarks>
26        /// <para>Source: https://oeis.org/A000108/list </para>
27        /// <para>Источник: https://oeis.org/A000108/list </para>
28        /// </remarks>
29        private static readonly ulong[] _catalans =
30        {
31            1, 1, 2, 5, 14, 42, 132, 429, 1430, 4862, 16796, 58786, 208012,
32            742900, 2674440, 9694845, 35357670, 129644790, 477638700, 1767263190,
33            6564120420, 24466267020, 91482563640, 343059613650, 1289904147324,
34            ↪ 4861946401452,
35            18367353072152, 69533550916004, 263747951750360, 1002242216651368,
36            ↪ 3814986502092304,
37            14544636039226909, 55534064877048198, 212336130412243110, 812944042149730764,
38            ↪ 3116285494907301262, 11959798385860453492
39        };
40
41        public static readonly ulong MaximumFactorialNumber = 20;
42        public static readonly ulong MaximumCatalanIndex = 36;
43
44        /// <summary>
45        /// <para>Returns the product of all positive integers less than or equal to the number
46        ↪ specified as an argument.</para>
47        /// <para>Возвращает произведение всех положительных чисел меньше или равных указанному
48        ↪ в качестве аргумента числу.</para>
49        /// </summary>
50        /// <param name="n"><para>The maximum positive number that will participate in
51        ↪ factorial's product.</para><para>Максимальное положительное число, которое будет
52        ↪ участвовать в произведение факториала.</para></param>
53        /// <returns><para>The product of all positive integers less than or equal to the number
54        ↪ specified as an argument.</para><para>Произведение всех положительных чисел меньше
55        ↪ или равных указанному в качестве аргумента числу.</para></returns>
56        public static ulong Factorial(ulong n)
57        {
58            if (n >= 0 && n <= MaximumFactorialNumber)
59            {
60                return _factorials[n];
61            }
62            else
63            {
64                throw new ArgumentOutOfRangeException($"Only numbers from 0 to
65                ↪ {MaximumFactorialNumber} are supported by unsigned integer with 64 bits
66                ↪ length.");
67            }
68        }
69
70        /// <summary>
71        /// <para>Returns the Catalan Number with the number specified as an argument.</para>
72        /// <para>Возвращает Каталановое число с номером указанным в качестве аргумента.</para>
73        /// </summary>
74        /// <param name="n"><para>The number of Catalan number.</para><para>Номер Каталанового
75        ↪ числа.</para></param>
76        /// <returns><para>The Catalan Number with the number specified as an
77        ↪ argument.</para><para>Каталановое число с номером указанным в качестве
78        ↪ аргумента.</para></returns>
79        public static ulong Catalan(ulong n)
80        {
81

```

```

68         if (n >= 0 && n <= MaximumCatalanIndex)
69         {
70             return _catalans[n];
71         }
72         else
73         {
74             throw new ArgumentOutOfRangeException($"Only numbers from 0 to
              ↳ {MaximumCatalanIndex} are supported by unsigned integer with 64 bits
              ↳ length.");
75         }
76     }
77
78     [MethodImpl(MethodImplOptions.AggressiveInlining)]
79     public static bool IsPowerOfTwo(ulong x) => (x & x - 1) == 0;
80
81     [MethodImpl(MethodImplOptions.AggressiveInlining)]
82     public static T Abs<T>(T x) => Math<T>.Abs(x);
83
84     [MethodImpl(MethodImplOptions.AggressiveInlining)]
85     public static T Negate<T>(T x) => Math<T>.Negate(x);
86 }
87 }

```

1.8 ./csharp/Platform.Numbers/MathExtensions.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Numbers
6  {
7      /// <summary>
8      /// <para>Provides a set of extension methods that perform mathematical operations on
9      ↳ arbitrary object types.</para>
10     /// <para>Предоставляет набор методов расширения выполняющих математические операции для
11     ↳ объектов произвольного типа.</para>
12     /// </summary>
13     public static class MathExtensions
14     {
15         /// <summary>
16         /// <para>Takes a module from a number.</para>
17         /// <para>Берёт модуль от числа.</para>
18         /// </summary>
19         /// <param name = "x">
20         /// <para>The number from which to take the absolute value.</para>
21         /// <para>Число от которого необходимо взять абсолютное значение.</para>
22         /// </param>
23         /// <returns>
24         /// <para>The absolute value of a number.</para>
25         /// <para>Абсолютное значение числа.</para>
26         /// </returns>
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         public static T Abs<T>(this ref T x) where T : struct => x = Math<T>.Abs(x);
29
30         /// <summary>
31         /// <para>Makes a number negative.</para>
32         /// <para>Делает число отрицательным.</para>
33         /// </summary>
34         /// <param name = "x">
35         /// <para>The number to be made negative.</para>
36         /// <para>Число которое нужно сделать отрицательным.</para>
37         /// </param>
38         /// <returns>
39         /// <para>Negative number.</para>
40         /// <para>Отрицательное число.</para>
41         /// </returns>
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         public static T Negate<T>(this ref T x) where T : struct => x = Math<T>.Negate(x);
44     }
45 }

```

1.9 ./csharp/Platform.Numbers/Math[T].cs

```

1  using System;
2  using System.Runtime.CompilerServices;
3  using Platform.Exceptions;
4  using Platform.Reflection;
5
6  // ReSharper disable StaticFieldInGenericType
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

```

```

8
9 namespace Platform.Numbers
10 {
11     public static class Math<T>
12     {
13         public static readonly Func<T, T> Abs = CompileAbsDelegate();
14         public static readonly Func<T, T> Negate = CompileNegateDelegate();
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         private static Func<T, T> CompileAbsDelegate()
18         {
19             return DelegateHelpers.Compile<Func<T, T>>(emitter =>
20             {
21                 Ensure.Always.IsNumeric<T>();
22                 emitter.LoadArgument(0);
23                 if (NumericType<T>.IsSigned)
24                 {
25                     emitter.Call(typeof(System.Math).GetMethod("Abs", Types<T>.Array));
26                 }
27                 emitter.Return();
28             });
29         }
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         private static Func<T, T> CompileNegateDelegate()
33         {
34             return DelegateHelpers.Compile<Func<T, T>>(emitter =>
35             {
36                 emitter.LoadArgument(0);
37                 emitter.Negate();
38                 emitter.Return();
39             });
40         }
41     }
42 }

```

1.10 ./csharp/Platform.Numbers.Tests/ArithmeticExtensionsTests.cs

```

1 using Xunit;
2
3 namespace Platform.Numbers.Tests
4 {
5     public static class ArithmeticExtensionsTests
6     {
7         [Fact]
8         public static void IncrementTest()
9         {
10             var number = 0UL;
11             var returnValue = number.Increment();
12             Assert.Equal(1UL, returnValue);
13             Assert.Equal(1UL, number);
14         }
15
16         [Fact]
17         public static void DecrementTest()
18         {
19             var number = 1UL;
20             var returnValue = number.Decrement();
21             Assert.Equal(0UL, returnValue);
22             Assert.Equal(0UL, number);
23         }
24     }
25 }

```

1.11 ./csharp/Platform.Numbers.Tests/ArithmeticTests.cs

```

1 using System;
2 using Xunit;
3
4 namespace Platform.Numbers.Tests
5 {
6     public static class ArithmeticTests
7     {
8         [Fact]
9         public static void CompiledOperationsTest()
10        {
11            Assert.Equal(3, Arithmetic.Add(1, 2));
12            Assert.Equal(1, Arithmetic.Subtract(2, 1));
13            Assert.Equal(8, Arithmetic.Multiply(2, 4));
14            Assert.Equal(4, Arithmetic.Divide(8, 2));
15            Assert.Equal(2, Arithmetic.Increment(1));
16        }
17    }
18 }

```

```

16         Assert.Equal(1UL, Arithmetic.Decrement(2UL));
17         Assert.Throws<NotSupportedException>(() => Arithmetic<string>.Subtract("1", "2"));
18     }
19 }
20 }

```

1.12 ./csharp/Platform.Numbers.Tests/BitTests.cs

```

1  using System;
2  using Xunit;
3
4  namespace Platform.Numbers.Tests
5  {
6      public static class BitTests
7      {
8          [Theory]
9          [InlineData(00, -1)] // 0000 0000 (none, -1)
10         [InlineData(01, 00)] // 0000 0001 (first, 0)
11         [InlineData(08, 03)] // 0000 1000 (forth, 3)
12         [InlineData(88, 03)] // 0101 1000 (forth, 3)
13         public static void GetLowestBitPositionTest(ulong value, int expectedPosition)
14         {
15             Assert.True(Bit.GetLowestPosition(value) == expectedPosition);
16         }
17
18         [Fact]
19         public static void ByteBitwiseOperationsTest()
20         {
21             Assert.True(Bit<byte>.Not(2) == unchecked((byte)~2));
22             Assert.True(Bit<byte>.Or(1, 2) == (1 | 2));
23             Assert.True(Bit<byte>.And(1, 2) == (1 & 2));
24             Assert.True(Bit<byte>.ShiftLeft(1, 2) == (1 << 2));
25             Assert.True(Bit<byte>.ShiftRight(1, 2) == (1 >> 2));
26         }
27
28         [Fact]
29         public static void UInt16BitwiseOperationsTest()
30         {
31             Assert.True(Bit<ushort>.Not(2) == unchecked((ushort)~2));
32             Assert.True(Bit<ushort>.Or(1, 2) == (1 | 2));
33             Assert.True(Bit<ushort>.And(1, 2) == (1 & 2));
34             Assert.True(Bit<ushort>.ShiftLeft(1, 2) == (1 << 2));
35             Assert.True(Bit<ushort>.ShiftRight(1, 2) == (1 >> 2));
36         }
37
38         [Fact]
39         public static void UInt32BitwiseOperationsTest()
40         {
41             Assert.True(Bit<uint>.Not(2) == unchecked((uint)~2));
42             Assert.True(Bit<uint>.Or(1, 2) == (1 | 2));
43             Assert.True(Bit<uint>.And(1, 2) == (1 & 2));
44             Assert.True(Bit<uint>.ShiftLeft(1, 2) == (1 << 2));
45             Assert.True(Bit<uint>.ShiftRight(1, 2) == (1 >> 2));
46         }
47
48         [Fact]
49         public static void UInt64BitwiseOperationsTest()
50         {
51             Assert.True(Bit<ulong>.Not(2) == unchecked((ulong)~2));
52             Assert.True(Bit<ulong>.Or(1, 2) == (1 | 2));
53             Assert.True(Bit<ulong>.And(1, 2) == (1 & 2));
54             Assert.True(Bit<ulong>.ShiftLeft(1, 2) == (1 << 2));
55             Assert.True(Bit<ulong>.ShiftRight(1, 2) == (1 >> 2));
56         }
57
58         [Fact]
59         public static void PartialReadWriteTest()
60         {
61             {
62                 uint firstValue = 1;
63                 uint secondValue = 1543;
64
65                 // Pack (join) two values at the same time
66                 uint value = secondValue << 1 | firstValue;
67
68                 uint unpackagedFirstValue = value & 1;
69                 uint unpackagedSecondValue = (value & 0xFFFFFFF0) >> 1;
70
71                 Assert.True(firstValue == unpackagedFirstValue);
72                 Assert.True(secondValue == unpackagedSecondValue);

```

```

73
74 // Using universal functions:
75 Assert.True(PartialRead(value, 0, 1) == firstValue);
76 Assert.True(PartialRead(value, 1, -1) == secondValue);
77
78 firstValue = 0;
79 secondValue = 6892;
80
81 value = PartialWrite(value, firstValue, 0, 1);
82 value = PartialWrite(value, secondValue, 1, -1);
83
84 Assert.True(PartialRead(value, 0, 1) == firstValue);
85 Assert.True(PartialRead(value, 1, -1) == secondValue);
86 }
87
88 {
89     uint firstValue = 1;
90     uint secondValue = 1543;
91
92     // Pack (join) two values at the same time
93     uint value = secondValue << 1 | firstValue;
94
95     uint unpackagedFirstValue = value & 1;
96     uint unpackagedSecondValue = (value & 0xFFFFFFF0) >> 1;
97
98     Assert.True(firstValue == unpackagedFirstValue);
99     Assert.True(secondValue == unpackagedSecondValue);
100
101     // Using universal functions:
102     Assert.True(Bit.PartialRead(value, 0, 1) == firstValue);
103     Assert.True(Bit.PartialRead(value, 1, -1) == secondValue);
104
105     firstValue = 0;
106     secondValue = 6892;
107
108     value = Bit.PartialWrite(value, firstValue, 0, 1);
109     value = Bit.PartialWrite(value, secondValue, 1, -1);
110
111     Assert.True(Bit.PartialRead(value, 0, 1) == firstValue);
112     Assert.True(Bit.PartialRead(value, 1, -1) == secondValue);
113 }
114
115 {
116     uint firstValue = 1;
117     uint secondValue = 1543;
118
119     // Pack (join) two values at the same time
120     uint value = secondValue << 1 | firstValue;
121
122     uint unpackagedFirstValue = value & 1;
123     uint unpackagedSecondValue = (value & 0xFFFFFFF0) >> 1;
124
125     Assert.True(firstValue == unpackagedFirstValue);
126     Assert.True(secondValue == unpackagedSecondValue);
127
128     // Using universal functions:
129     var readMasksAndShiftFor0And1 = GetReadMaskAndShift(0, 1);
130     var readMasksAndShiftFor1AndMinus1 = GetReadMaskAndShift(1, -1);
131     var writeMasksAndShiftFor0And1 = GetWriteMasksAndShift(0, 1);
132     var writeMasksAndShiftFor1AndMinus1 = GetWriteMasksAndShift(1, -1);
133
134     Assert.True(PartialRead(value, readMasksAndShiftFor0And1) == firstValue);
135     Assert.True(PartialRead(value, readMasksAndShiftFor1AndMinus1) == secondValue);
136
137     firstValue = 0;
138     secondValue = 6892;
139
140     value = PartialWrite(value, firstValue, writeMasksAndShiftFor0And1);
141     value = PartialWrite(value, secondValue, writeMasksAndShiftFor1AndMinus1);
142
143     Assert.True(PartialRead(value, readMasksAndShiftFor0And1) == firstValue);
144     Assert.True(PartialRead(value, readMasksAndShiftFor1AndMinus1) == secondValue);
145 }
146 }
147
148 // TODO: Can be optimized using precalculation of TargetMask and SourceMask
149 private static uint PartialWrite(uint target, uint source, int shift, int limit)
150 {
151     if (shift < 0)
152     {
153         shift = 32 + shift;

```

```

154     }
155     if (limit < 0)
156     {
157         limit = 32 + limit;
158     }
159     var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
160     var targetMask = ~(sourceMask << shift);
161     return target & targetMask | (source & sourceMask) << shift;
162 }
163
164 private static uint PartialRead(uint target, int shift, int limit)
165 {
166     if (shift < 0)
167     {
168         shift = 32 + shift;
169     }
170     if (limit < 0)
171     {
172         limit = 32 + limit;
173     }
174     var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
175     var targetMask = sourceMask << shift;
176     return (target & targetMask) >> shift;
177 }
178
179 private static Tuple<uint, uint, int> GetWriteMasksAndShift(int shift, int limit)
180 {
181     if (shift < 0)
182     {
183         shift = 32 + shift;
184     }
185     if (limit < 0)
186     {
187         limit = 32 + limit;
188     }
189     var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
190     var targetMask = ~(sourceMask << shift);
191     return new Tuple<uint, uint, int>(targetMask, sourceMask, shift);
192 }
193
194 private static Tuple<uint, int> GetReadMaskAndShift(int shift, int limit)
195 {
196     if (shift < 0)
197     {
198         shift = 32 + shift;
199     }
200     if (limit < 0)
201     {
202         limit = 32 + limit;
203     }
204     var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
205     var targetMask = sourceMask << shift;
206     return new Tuple<uint, int>(targetMask, shift);
207 }
208
209 private static uint PartialWrite(uint target, uint targetMask, uint source, uint
    → sourceMask, int shift) => target & targetMask | (source & sourceMask) << shift;
210
211 private static uint PartialWrite(uint target, uint source, Tuple<uint, uint, int>
    → masksAndShift) => PartialWrite(target, masksAndShift.Item1, source,
    → masksAndShift.Item2, masksAndShift.Item3);
212
213 private static uint PartialRead(uint target, uint targetMask, int shift) => (target &
    → targetMask) >> shift;
214
215 private static uint PartialRead(uint target, Tuple<uint, int> masksAndShift) =>
    → PartialRead(target, masksAndShift.Item1, masksAndShift.Item2);
216
217 [Fact]
218 public static void BugWithLoadingConstantOf8Test()
219 {
220     Bit<byte>.PartialWrite(0, 1, 5, -5);
221 }
222 }
223 }

```

1.13 ./csharp/Platform.Numbers.Tests/MathExtensionsTests.cs

```

1 using Xunit;
2

```

```

3 namespace Platform.Numbers.Tests
4 {
5     public static class MathExtensionsTests
6     {
7         [Fact]
8         public static void AbsTest()
9         {
10             var number = -1L;
11             var returnValue = number.Abs();
12             Assert.Equal(1L, returnValue);
13             Assert.Equal(1L, number);
14         }
15
16         [Fact]
17         public static void NegateTest()
18         {
19             var number = 2L;
20             var returnValue = number.Negate();
21             Assert.Equal(-2L, returnValue);
22             Assert.Equal(-2L, number);
23         }
24
25         [Fact]
26         public static void UnsignedNegateTest()
27         {
28             var number = 2UL;
29             var returnValue = number.Negate();
30             Assert.Equal(18446744073709551614, returnValue);
31             Assert.Equal(18446744073709551614, number);
32         }
33     }
34 }

```

1.14 ./csharp/Platform.Numbers.Tests/MathTests.cs

```

1 using Xunit;
2
3 namespace Platform.Numbers.Tests
4 {
5     public static class MathTests
6     {
7         [Fact]
8         public static void CompiledOperationsTest()
9         {
10             Assert.True(Math.Abs(Arithmetic<double>.Subtract(3D, 2D) - 1D) < 0.01);
11         }
12     }
13 }

```

1.15 ./csharp/Platform.Numbers.Tests/SystemTests.cs

```

1 using Xunit;
2
3 namespace Platform.Numbers.Tests
4 {
5     public static class SystemTests
6     {
7         [Fact]
8         public static void PossiblePackTwoValuesIntoOneTest()
9         {
10             uint value = 0;
11
12             // Set one to first bit
13             value |= 1;
14
15             Assert.True(value == 1);
16
17             // Set zero to first bit
18             value &= 0xFFFFFFFF;
19
20             // Get first bit
21             uint read = value & 1;
22
23             Assert.True(read == 0);
24
25             uint firstValue = 1;
26             uint secondValue = 1543;
27
28             // Pack (join) two values at the same time
29             value = (secondValue << 1) | firstValue;
30
31             uint unpackagedFirstValue = value & 1;

```



```

32     uint unpackagedSecondValue = (value & 0xFFFFFFFF) >> 1;
33
34     Assert.True(firstValue == unpackagedFirstValue);
35     Assert.True(secondValue == unpackagedSecondValue);
36
37     // Using universal functions:
38
39     Assert.True(PartialRead(value, 0, 1) == firstValue);
40     Assert.True(PartialRead(value, 1, -1) == secondValue);
41
42     firstValue = 0;
43     secondValue = 6892;
44
45     value = PartialWrite(value, firstValue, 0, 1);
46     value = PartialWrite(value, secondValue, 1, -1);
47
48     Assert.True(PartialRead(value, 0, 1) == firstValue);
49     Assert.True(PartialRead(value, 1, -1) == secondValue);
50 }
51
52 private static uint PartialWrite(uint target, uint source, int shift, int limit)
53 {
54     if (shift < 0)
55     {
56         shift = 32 + shift;
57     }
58     if (limit < 0)
59     {
60         limit = 32 + limit;
61     }
62     var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
63     var targetMask = ~(sourceMask << shift);
64     return (target & targetMask) | ((source & sourceMask) << shift);
65 }
66
67 private static uint PartialRead(uint target, int shift, int limit)
68 {
69     if (shift < 0)
70     {
71         shift = 32 + shift;
72     }
73     if (limit < 0)
74     {
75         limit = 32 + limit;
76     }
77     var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
78     var targetMask = sourceMask << shift;
79     return (target & targetMask) >> shift;
80 }
81 }
82

```

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