1.1 ./Platform.Numbers/Arithmetic.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class Arithmetic
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Add<T>(T x, T y) => Arithmetic<T>.Add(x, y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Subtract<T>(T x, T y) => Arithmetic<T>.Subtract(x, y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Subtract<T>(Integer<T> x, Integer<T> y) => Arithmetic<T>.Subtract(x, y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Increment<T>(T x) => Arithmetic<T>.Increment(x);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Decrement<T>(T x) => Arithmetic<T>.Decrement(x);
    }
}
```

1.2 ./Platform.Numbers/ArithmeticExtensions.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class ArithmeticExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Decrement<T>(this ref T x) where T : struct => x =
        ↪  Arithmetic<T>.Decrement(x);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Increment<T>(this ref T x) where T : struct => x =
        ↪  Arithmetic<T>.Increment(x);
    }
}
```

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

```
using System;
using Platform.Exceptions;
using Platform.Reflection;

// ReSharper disable StaticFieldInGenericType
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class Arithmetic<T>
    {
        public static readonly Func<T, T, T> Add = CompileAddDelegate();
        public static readonly Func<T, T, T> Subtract = CompileSubtractDelegate();
        public static readonly Func<T, T> Increment = CompileIncrementDelegate();
        public static readonly Func<T, T> Decrement = CompileDecrementDelegate();

        private static Func<T, T, T> CompileAddDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                emiter.LoadArguments(0, 1);
                emiter.Add();
                emiter.Return();
            });
        }

        private static Func<T, T, T> CompileSubtractDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
```

```
                emiter.LoadArguments(0, 1);
                emiter.Subtract();
                emiter.Return();
            });
        }

        private static Func<T, T> CompileIncrementDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                emiter.LoadArgument(0);
                emiter.Increment<T>();
                emiter.Return();
            });
        }

        private static Func<T, T> CompileDecrementDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                emiter.LoadArgument(0);
                emiter.Decrement<T>();
                emiter.Return();
            });
        }
    }
}
```

1.4 ./Platform.Numbers/Bit.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class Bit
    {
        public static long Count(long x)
        {
            long n = 0;
            while (x != 0)
            {
                n++;
                x &= x - 1;
            }
            return n;
        }

        public static int GetLowestPosition(ulong value)
        {
            if (value == 0)
            {
                return -1;
            }
            var position = 0;
            while ((value & 1UL) == 0)
            {
                value >>= 1;
                ++position;
            }
            return position;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Not<T>(T x) => Bit<T>.Not(x);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Or<T>(T x, T y) => Bit<T>.Or(x, y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T And<T>(T x, T y) => Bit<T>.And(x, y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T ShiftLeft<T>(T x, int y) => Bit<T>.ShiftLeft(x, y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T ShiftRight<T>(T x, int y) => Bit<T>.ShiftRight(x, y);

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T PartialWrite<T>(T target, T source, int shift, int limit) =>
        ↪  Bit<T>.PartialWrite(target, source, shift, limit);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T PartialRead<T>(T target, int shift, int limit) =>
        ↪  Bit<T>.PartialRead(target, shift, limit);
    }
}
```

1.5 ./Platform.Numbers/BitExtensions.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class BitwiseExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Not<T>(this ref T target) where T : struct => target = Bit.Not(target);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T PartialWrite<T>(this ref T target, T source, int shift, int limit) where
        ↪  T : struct => target = Bit<T>.PartialWrite(target, source, shift, limit);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T PartialRead<T>(this T target, int shift, int limit) =>
        ↪  Bit<T>.PartialRead(target, shift, limit);
    }
}
```

1.6 ./Platform.Numbers/Bit[T].cs

```
using System;
using Platform.Exceptions;
using Platform.Reflection;

// ReSharper disable StaticFieldInGenericType
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class Bit<T>
    {
        public static readonly Func<T, T> Not = CompileNotDelegate();
        public static readonly Func<T, T, T> Or = CompileOrDelegate();
        public static readonly Func<T, T, T> And = CompileAndDelegate();
        public static readonly Func<T, int, T> ShiftLeft = CompileShiftLeftDelegate();
        public static readonly Func<T, int, T> ShiftRight = CompileShiftRightDelegate();
        public static readonly Func<T, T, int, int, T> PartialWrite =
        ↪  CompilePartialWriteDelegate();
        public static readonly Func<T, int, int, T> PartialRead = CompilePartialReadDelegate();

        private static Func<T, T> CompileNotDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                emiter.LoadArguments(0);
                emiter.Not();
                emiter.Return();
            });
        }

        private static Func<T, T, T> CompileOrDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                emiter.LoadArguments(0, 1);
                emiter.Or();
                emiter.Return();
            });
        }

        private static Func<T, T, T> CompileAndDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T, T>>(emiter =>
```

```
45              {
46                  Ensure.Always.IsNumeric<T>();
47                  emiter.LoadArguments(0, 1);
48                  emiter.And();
49                  emiter.Return();
50              });
51          }
52
53          private static Func<T, int, T> CompileShiftLeftDelegate()
54          {
55              return DelegateHelpers.Compile<Func<T, int, T>>(emiter =>
56              {
57                  Ensure.Always.IsNumeric<T>();
58                  emiter.LoadArguments(0, 1);
59                  emiter.ShiftLeft();
60                  emiter.Return();
61              });
62          }
63
64          private static Func<T, int, T> CompileShiftRightDelegate()
65          {
66              return DelegateHelpers.Compile<Func<T, int, T>>(emiter =>
67              {
68                  Ensure.Always.IsNumeric<T>();
69                  emiter.LoadArguments(0, 1);
70                  emiter.ShiftRight();
71                  emiter.Return();
72              });
73          }
74
75          private static Func<T, T, int, int, T> CompilePartialWriteDelegate()
76          {
77              return DelegateHelpers.Compile<Func<T, T, int, int, T>>(emiter =>
78              {
79                  Ensure.Always.IsNumeric<T>();
80                  var constants = GetConstants();
81                  var bitsNumber = constants.Item1;
82                  var numberFilledWithOnes = constants.Item2;
83                  ushort shiftArgument = 2;
84                  ushort limitArgument = 3;
85                  var checkLimit = emiter.DefineLabel();
86                  var calculateSourceMask = emiter.DefineLabel();
87                  // Check shift
88                  emiter.LoadArgument(shiftArgument);
89                  emiter.LoadConstant(0);
90                  emiter.BranchIfGreaterOrEqual(checkLimit); // Skip fix
91                  // Fix shift
92                  emiter.LoadConstant(bitsNumber);
93                  emiter.LoadArgument(shiftArgument);
94                  emiter.Add();
95                  emiter.StoreArgument(shiftArgument);
96                  emiter.MarkLabel(checkLimit);
97                  // Check limit
98                  emiter.LoadArgument(limitArgument);
99                  emiter.LoadConstant(0);
100                 emiter.BranchIfGreaterOrEqual(calculateSourceMask); // Skip fix
101                 // Fix limit
102                 emiter.LoadConstant(bitsNumber);
103                 emiter.LoadArgument(limitArgument);
104                 emiter.Add();
105                 emiter.StoreArgument(limitArgument);
106                 emiter.MarkLabel(calculateSourceMask);
107                 var sourceMask = emiter.DeclareLocal<T>();
108                 var targetMask = emiter.DeclareLocal<T>();
109                 emiter.LoadConstant(typeof(T), numberFilledWithOnes);
110                 emiter.LoadArgument(limitArgument);
111                 emiter.ShiftLeft();
112                 emiter.Not();
113                 emiter.LoadConstant(typeof(T), numberFilledWithOnes);
114                 emiter.And();
115                 emiter.StoreLocal(sourceMask);
116                 emiter.LoadLocal(sourceMask);
117                 emiter.LoadArgument(shiftArgument);
118                 emiter.ShiftLeft();
119                 emiter.Not();
120                 emiter.StoreLocal(targetMask);
121                 emiter.LoadArgument(0); // target
122                 emiter.LoadLocal(targetMask);
```

```
                emiter.And();
                emiter.LoadArgument(1); // source
                emiter.LoadLocal(sourceMask);
                emiter.And();
                emiter.LoadArgument(shiftArgument);
                emiter.ShiftLeft();
                emiter.Or();
                emiter.Return();
            });
        }

        private static Func<T, int, int, T> CompilePartialReadDelegate()
        {
            return DelegateHelpers.Compile<Func<T, int, int, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                var constants = GetConstants();
                var bitsNumber = constants.Item1;
                var numberFilledWithOnes = constants.Item2;
                ushort shiftArgument = 1;
                ushort limitArgument = 2;
                var checkLimit = emiter.DefineLabel();
                var calculateSourceMask = emiter.DefineLabel();
                // Check shift
                emiter.LoadArgument(shiftArgument);
                emiter.LoadConstant(0);
                emiter.BranchIfGreaterOrEqual(checkLimit); // Skip fix
                // Fix shift
                emiter.LoadConstant(bitsNumber);
                emiter.LoadArgument(shiftArgument);
                emiter.Add();
                emiter.StoreArgument(shiftArgument);
                emiter.MarkLabel(checkLimit);
                // Check limit
                emiter.LoadArgument(limitArgument);
                emiter.LoadConstant(0);
                emiter.BranchIfGreaterOrEqual(calculateSourceMask); // Skip fix
                // Fix limit
                emiter.LoadConstant(bitsNumber);
                emiter.LoadArgument(limitArgument);
                emiter.Add();
                emiter.StoreArgument(limitArgument);
                emiter.MarkLabel(calculateSourceMask);
                var sourceMask = emiter.DeclareLocal<T>();
                var targetMask = emiter.DeclareLocal<T>();
                emiter.LoadConstant(typeof(T), numberFilledWithOnes);
                emiter.LoadArgument(limitArgument); // limit
                emiter.ShiftLeft();
                emiter.Not();
                emiter.LoadConstant(typeof(T), numberFilledWithOnes);
                emiter.And();
                emiter.StoreLocal(sourceMask);
                emiter.LoadLocal(sourceMask);
                emiter.LoadArgument(shiftArgument);
                emiter.ShiftLeft();
                emiter.StoreLocal(targetMask);
                emiter.LoadArgument(0); // target
                emiter.LoadLocal(targetMask);
                emiter.And();
                emiter.LoadArgument(shiftArgument);
                emiter.ShiftRight();
                emiter.Return();
            });
        }

        private static Tuple<int, T> GetConstants()
        {
            var type = typeof(T);
            if (type == typeof(ulong))
            {
                return new Tuple<int, T>(64, (T)(object)ulong.MaxValue);
            }
            if (type == typeof(uint))
            {
                return new Tuple<int, T>(32, (T)(object)uint.MaxValue);
            }
            if (type == typeof(ushort))
            {
```

```
                return new Tuple<int, T>(16, (T)(object)ushort.MaxValue);
            }
            if (type == typeof(byte))
            {
                return new Tuple<int, T>(8, (T)(object)byte.MaxValue);
            }
            throw new NotSupportedException();
        }
    }
}
```

1.7 ./Platform.Numbers/Integer.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public struct Integer : IEquatable<Integer>
    {
        public readonly ulong Value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Integer(ulong value) => Value = value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(ulong integer) => new Integer(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(long integer) => To.UInt64(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(uint integer) => new Integer(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(int integer) => To.UInt64(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(ushort integer) => new Integer(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(short integer) => To.UInt64(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(byte integer) => new Integer(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(sbyte integer) => To.UInt64(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(bool integer) => To.UInt64(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator ulong(Integer integer) => integer.Value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator long(Integer integer) => To.Int64(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator uint(Integer integer) => To.UInt32(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator int(Integer integer) => To.Int32(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator ushort(Integer integer) => To.UInt16(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator short(Integer integer) => To.Int16(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator byte(Integer integer) => To.Byte(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator sbyte(Integer integer) => To.SByte(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator bool(Integer integer) => To.Boolean(integer.Value);
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(Integer other) => Value == other.Value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override string ToString() => Value.ToString();
    }
}
```

1.8 ./Platform.Numbers/Integer[T].cs

```
using System;
using System.Runtime.CompilerServices;
using System.Collections.Generic;
using Platform.Exceptions;
using Platform.Reflection;
using Platform.Converters;

// ReSharper disable StaticFieldInGenericType
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
#pragma warning disable RECS0108 // Warns about static fields in generic types

namespace Platform.Numbers
{
    public struct Integer<T> : IEquatable<Integer<T>>
    {
        private static readonly EqualityComparer<T> _equalityComparer =
        ↪  EqualityComparer<T>.Default;
        private static readonly Func<ulong, Integer<T>> _create;

        public static readonly T Zero;
        public static readonly T One;
        public static readonly T Two;

        public readonly T Value;

        static Integer()
        {
            _create = CompileCreateDelegate();
            try
            {
                Zero = default;
                One = Arithmetic.Increment(Zero);
                Two = Arithmetic.Increment(One);
            }
            catch (Exception exception)
            {
                exception.Ignore();
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Integer(T value) => Value = value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer(Integer<T> integer)
        {
            if (typeof(T) == typeof(Integer))
            {
                return (Integer)(object)integer.Value;
            }
            return Convert.ToUInt64(integer.Value);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator ulong(Integer<T> integer) => ((Integer)integer).Value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator T(Integer<T> integer) => integer.Value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer<T>(T integer) => new Integer<T>(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer<T>(ulong integer) => _create(integer);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer<T>(Integer integer) => _create(integer.Value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Integer<T>(long integer) => To.UInt64(integer);
```

```
70
71          [MethodImpl(MethodImplOptions.AggressiveInlining)]
72          public static implicit operator Integer<T>(uint integer) => new Integer(integer);
73
74          [MethodImpl(MethodImplOptions.AggressiveInlining)]
75          public static implicit operator Integer<T>(int integer) => To.UInt64(integer);
76
77          [MethodImpl(MethodImplOptions.AggressiveInlining)]
78          public static implicit operator Integer<T>(ushort integer) => new Integer(integer);
79
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          public static implicit operator Integer<T>(short integer) => To.UInt64(integer);
82
83          [MethodImpl(MethodImplOptions.AggressiveInlining)]
84          public static implicit operator Integer<T>(byte integer) => new Integer(integer);
85
86          [MethodImpl(MethodImplOptions.AggressiveInlining)]
87          public static implicit operator Integer<T>(sbyte integer) => To.UInt64(integer);
88
89          [MethodImpl(MethodImplOptions.AggressiveInlining)]
90          public static implicit operator Integer<T>(bool integer) => To.UInt64(integer);
91
92          [MethodImpl(MethodImplOptions.AggressiveInlining)]
93          public static implicit operator long(Integer<T> integer) => To.Int64(integer);
94
95          [MethodImpl(MethodImplOptions.AggressiveInlining)]
96          public static implicit operator uint(Integer<T> integer) => To.UInt32(integer);
97
98          [MethodImpl(MethodImplOptions.AggressiveInlining)]
99          public static implicit operator int(Integer<T> integer) => To.Int32(integer);
100
101         [MethodImpl(MethodImplOptions.AggressiveInlining)]
102         public static implicit operator ushort(Integer<T> integer) => To.UInt16(integer);
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         public static implicit operator short(Integer<T> integer) => To.Int16(integer);
106
107         [MethodImpl(MethodImplOptions.AggressiveInlining)]
108         public static implicit operator byte(Integer<T> integer) => To.Byte(integer);
109
110         [MethodImpl(MethodImplOptions.AggressiveInlining)]
111         public static implicit operator sbyte(Integer<T> integer) => To.SByte(integer);
112
113         [MethodImpl(MethodImplOptions.AggressiveInlining)]
114         public static implicit operator bool(Integer<T> integer) => To.Boolean(integer);
115
116         [MethodImpl(MethodImplOptions.AggressiveInlining)]
117         public bool Equals(Integer<T> other) => _equalityComparer.Equals(Value, other.Value);
118
119         [MethodImpl(MethodImplOptions.AggressiveInlining)]
120         public override string ToString() => Value.ToString();
121
122         private static Func<ulong, Integer<T>> CompileCreateDelegate()
123         {
124             return DelegateHelpers.Compile<Func<ulong, Integer<T>>>(emiter =>
125             {
126                 if (typeof(T) != typeof(Integer))
127                 {
128                     Ensure.Always.CanBeNumeric<T>();
129                 }
130                 emiter.LoadArgument(0);
131                 if (typeof(T) != typeof(ulong) && typeof(T) != typeof(Integer))
132                 {
133                     emiter.Call(typeof(To).GetMethod(typeof(T).Name, Types<ulong>.Array));
134                 }
135                 if (NumericType<T>.IsNullable)
136                 {
137                     emiter.NewObject(typeof(T), NumericType<T>.UnderlyingType);
138                 }
139                 if (typeof(T) == typeof(Integer))
140                 {
141                     emiter.NewObject(typeof(Integer), typeof(ulong));
142                 }
143                 emiter.NewObject(typeof(Integer<T>), typeof(T));
144                 emiter.Return();
145             });
146         }
147     }
148 }
```

1.9 ./Platform.Numbers/Math.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    /// <remarks>
    /// Resizable array (FileMappedMemory) for values cache may be used. or cached oeis.org
    /// </remarks>
    public static class Math
    {
        /// <remarks>
        /// Source: https://oeis.org/A000142/list
        /// </remarks>
        private static readonly ulong[] _factorials =
        {
            1, 1, 2, 6, 24, 120, 720, 5040, 40320, 362880, 3628800, 39916800,
            479001600, 6227020800, 87178291200, 1307674368000, 20922789888000,
            355687428096000, 6402373705728000, 121645100408832000, 2432902008176640000
        };

        /// <remarks>
        /// Source: https://oeis.org/A000108/list
        /// </remarks>
        private static readonly ulong[] _catalans =
        {
            1, 1, 2, 5, 14, 42, 132, 429, 1430, 4862, 16796, 58786, 208012,
            742900, 2674440, 9694845, 35357670, 129644790, 477638700, 1767263190,
            6564120420, 24466267020, 91482563640, 343059613650, 1289904147324, 4861946401452,
            18367353072152, 69533550916004, 263747951750360, 1002242216651368, 3814986502092304
        };

        public static double Factorial(double n)
        {
            if (n <= 1)
            {
                return 1;
            }
            if (n < _factorials.Length)
            {
                return _factorials[(int)n];
            }
            return n * Factorial(n - 1);
        }

        public static double Catalan(double n)
        {
            if (n <= 1)
            {
                return 1;
            }
            if (n < _catalans.Length)
            {
                return _catalans[(int)n];
            }
            return Factorial(2 * n) / (Factorial(n + 1) * Factorial(n));
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool IsPowerOfTwo(ulong x) => (x & x - 1) == 0;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Abs<T>(T x) => Math<T>.Abs(x);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Negate<T>(T x) => Math<T>.Negate(x);
    }
}
```

1.10 ./Platform.Numbers/MathExtensions.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class MathExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        public static T Abs<T>(this ref T x) where T : struct => x = Math<T>.Abs(x);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static T Negate<T>(this ref T x) where T : struct => x = Math<T>.Negate(x);
    }
}
```

1.11 ./Platform.Numbers/Math[T].cs

```
using System;
using System.Reflection;
using Platform.Exceptions;
using Platform.Reflection;

// ReSharper disable StaticFieldInGenericType
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Numbers
{
    public static class Math<T>
    {
        public static readonly Func<T, T> Abs = CompileAbsDelegate();
        public static readonly Func<T, T> Negate = CompileNegateDelegate();

        private static Func<T, T> CompileAbsDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T>>(emiter =>
            {
                Ensure.Always.IsNumeric<T>();
                emiter.LoadArgument(0);
                if (NumericType<T>.IsSigned)
                {
                    emiter.Call(typeof(System.Math).GetMethod("Abs", Types<T>.Array));
                }
                emiter.Return();
            });
        }

        private static Func<T, T> CompileNegateDelegate()
        {
            return DelegateHelpers.Compile<Func<T, T>>(emiter =>
            {
                emiter.LoadArgument(0);
                emiter.Negate();
                emiter.Return();
            });
        }
    }
}
```

1.12 ./Platform.Numbers.Tests/ArithmeticExtensionsTests.cs

```
using Xunit;

namespace Platform.Numbers.Tests
{
    public static class ArithmeticExtensionsTests
    {
        [Fact]
        public static void IncrementTest()
        {
            var number = 0UL;
            var returnValue = number.Increment();
            Assert.Equal(1UL, returnValue);
            Assert.Equal(1UL, number);
        }

        [Fact]
        public static void DecrementTest()
        {
            var number = 1UL;
            var returnValue = number.Decrement();
            Assert.Equal(0UL, returnValue);
            Assert.Equal(0UL, number);
        }
    }
}
```

1.13 ./Platform.Numbers.Tests/ArithmeticTests.cs

```
using System;
using Xunit;
```

```

namespace Platform.Numbers.Tests
{
    public static class ArithmeticTests
    {
        [Fact]
        public static void CompiledOperationsTest()
        {
            Assert.True(Arithmetic<short>.Add(1, 2) == 3);
            Assert.True(Arithmetic<short>.Subtract(2, 1) == 1);
            Assert.True(Arithmetic<byte>.Increment(1) == 2);
            Assert.True(Arithmetic<ulong>.Decrement(2) == 1);
            Assert.Throws<NotSupportedException>(() => Arithmetic<string>.Subtract("1", "2"));
        }
    }
}
```

1.14 ./Platform.Numbers.Tests/BitTests.cs

```
using System;
using Xunit;

namespace Platform.Numbers.Tests
{
    public static class BitTests
    {
        [Theory]
        [InlineData(00, -1)] // 0000 0000 (none, -1)
        [InlineData(01, 00)] // 0000 0001 (first, 0)
        [InlineData(08, 03)] // 0000 1000 (forth, 3)
        [InlineData(88, 03)] // 0101 1000 (forth, 3)
        public static void GetLowestBitPositionTest(ulong value, int expectedPosition)
        {
            Assert.True(Bit.GetLowestPosition(value) == expectedPosition);
        }

        [Fact]
        public static void ByteBitwiseOperationsTest()
        {
            Assert.True(Bit<byte>.Not(2) == unchecked((byte)~2));
            Assert.True(Bit<byte>.Or(1, 2) == (1 | 2));
            Assert.True(Bit<byte>.And(1, 2) == (1 & 2));
            Assert.True(Bit<byte>.ShiftLeft(1, 2) == (1 << 2));
            Assert.True(Bit<byte>.ShiftRight(1, 2) == (1 >> 2));
        }

        [Fact]
        public static void UInt16BitwiseOperationsTest()
        {
            Assert.True(Bit<ushort>.Not(2) == unchecked((ushort)~2));
            Assert.True(Bit<ushort>.Or(1, 2) == (1 | 2));
            Assert.True(Bit<ushort>.And(1, 2) == (1 & 2));
            Assert.True(Bit<ushort>.ShiftLeft(1, 2) == (1 << 2));
            Assert.True(Bit<ushort>.ShiftRight(1, 2) == (1 >> 2));
        }

        [Fact]
        public static void UInt32BitwiseOperationsTest()
        {
            Assert.True(Bit<uint>.Not(2) == unchecked((uint)~2));
            Assert.True(Bit<uint>.Or(1, 2) == (1 | 2));
            Assert.True(Bit<uint>.And(1, 2) == (1 & 2));
            Assert.True(Bit<uint>.ShiftLeft(1, 2) == (1 << 2));
            Assert.True(Bit<uint>.ShiftRight(1, 2) == (1 >> 2));
        }

        [Fact]
        public static void UInt64BitwiseOperationsTest()
        {
            Assert.True(Bit<ulong>.Not(2) == unchecked((ulong)~2));
            Assert.True(Bit<ulong>.Or(1, 2) == (1 | 2));
            Assert.True(Bit<ulong>.And(1, 2) == (1 & 2));
            Assert.True(Bit<ulong>.ShiftLeft(1, 2) == (1 << 2));
            Assert.True(Bit<ulong>.ShiftRight(1, 2) == (1 >> 2));
        }

        [Fact]
        public static void PartialReadWriteTest()
        {
            {
```

```
            uint firstValue = 1;
            uint secondValue = 1543;

            // Pack (join) two values at the same time
            uint value = secondValue << 1 | firstValue;

            uint unpackagedFirstValue = value & 1;
            uint unpackagedSecondValue = (value & 0xFFFFFFFE) >> 1;

            Assert.True(firstValue == unpackagedFirstValue);
            Assert.True(secondValue == unpackagedSecondValue);

            // Using universal functions:
            Assert.True(PartialRead(value, 0, 1) == firstValue);
            Assert.True(PartialRead(value, 1, -1) == secondValue);

            firstValue = 0;
            secondValue = 6892;

            value = PartialWrite(value, firstValue, 0, 1);
            value = PartialWrite(value, secondValue, 1, -1);

            Assert.True(PartialRead(value, 0, 1) == firstValue);
            Assert.True(PartialRead(value, 1, -1) == secondValue);
        }

        {
            uint firstValue = 1;
            uint secondValue = 1543;

            // Pack (join) two values at the same time
            uint value = secondValue << 1 | firstValue;

            uint unpackagedFirstValue = value & 1;
            uint unpackagedSecondValue = (value & 0xFFFFFFFE) >> 1;

            Assert.True(firstValue == unpackagedFirstValue);
            Assert.True(secondValue == unpackagedSecondValue);

            // Using universal functions:
            Assert.True(Bit.PartialRead(value, 0, 1) == firstValue);
            Assert.True(Bit.PartialRead(value, 1, -1) == secondValue);

            firstValue = 0;
            secondValue = 6892;

            value = Bit.PartialWrite(value, firstValue, 0, 1);
            value = Bit.PartialWrite(value, secondValue, 1, -1);

            Assert.True(Bit.PartialRead(value, 0, 1) == firstValue);
            Assert.True(Bit.PartialRead(value, 1, -1) == secondValue);
        }

        {
            uint firstValue = 1;
            uint secondValue = 1543;

            // Pack (join) two values at the same time
            uint value = secondValue << 1 | firstValue;

            uint unpackagedFirstValue = value & 1;
            uint unpackagedSecondValue = (value & 0xFFFFFFFE) >> 1;

            Assert.True(firstValue == unpackagedFirstValue);
            Assert.True(secondValue == unpackagedSecondValue);

            // Using universal functions:
            var readMasksAndShiftFor0And1 = GetReadMaskAndShift(0, 1);
            var readMasksAndShiftFor1AndMinus1 = GetReadMaskAndShift(1, -1);
            var writeMasksAndShiftFor0And1 = GetWriteMasksAndShift(0, 1);
            var writeMasksAndShiftFor1AndMinus1 = GetWriteMasksAndShift(1, -1);

            Assert.True(PartialRead(value, readMasksAndShiftFor0And1) == firstValue);
            Assert.True(PartialRead(value, readMasksAndShiftFor1AndMinus1) == secondValue);

            firstValue = 0;
            secondValue = 6892;

            value = PartialWrite(value, firstValue, writeMasksAndShiftFor0And1);
            value = PartialWrite(value, secondValue, writeMasksAndShiftFor1AndMinus1);

```

```
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  }
```

1.15 ./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  }
```

1.16 ./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  }
```

1.17 ./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 &= 0xFFFFFFFE;
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
```

```
            value = (secondValue << 1) | firstValue;

            uint unpackagedFirstValue = value & 1;
            uint unpackagedSecondValue = (value & 0xFFFFFFFE) >> 1;

            Assert.True(firstValue == unpackagedFirstValue);
            Assert.True(secondValue == unpackagedSecondValue);

            // Using universal functions:

            Assert.True(PartialRead(value, 0, 1) == firstValue);
            Assert.True(PartialRead(value, 1, -1) == secondValue);

            firstValue = 0;
            secondValue = 6892;

            value = PartialWrite(value, firstValue, 0, 1);
            value = PartialWrite(value, secondValue, 1, -1);

            Assert.True(PartialRead(value, 0, 1) == firstValue);
            Assert.True(PartialRead(value, 1, -1) == secondValue);
        }

        private static uint PartialWrite(uint target, uint source, int shift, int limit)
        {
            if (shift < 0)
            {
                shift = 32 + shift;
            }
            if (limit < 0)
            {
                limit = 32 + limit;
            }
            var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
            var targetMask = ~(sourceMask << shift);
            return (target & targetMask) | ((source & sourceMask) << shift);
        }

        private static uint PartialRead(uint target, int shift, int limit)
        {
            if (shift < 0)
            {
                shift = 32 + shift;
            }
            if (limit < 0)
            {
                limit = 32 + limit;
            }
            var sourceMask = ~(uint.MaxValue << limit) & uint.MaxValue;
            var targetMask = sourceMask << shift;
            return (target & targetMask) >> shift;
        }
    }
}
```

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