

23.6 Producer/Consumer Relationship: ArrayBlockingQueue

The best way to synchronize producer and consumer threads is to use classes from Java's `java.util.concurrent` package that *encapsulate the synchronization for you*. Java includes the class `ArrayBlockingQueue`—a fully implemented, *thread-safe buffer class* that implements interface `BlockingQueue`. This interface declares methods `put` and `take`. Method `put` places an element at the end of the `BlockingQueue`, waiting if the queue is full. Method `take` removes an element from the head of the `BlockingQueue`, waiting if the queue is empty. These methods make class `ArrayBlockingQueue` a good choice for implementing a shared buffer. Because method `put` blocks until there's room in the buffer to write data, and method `take` blocks until there's new data to read, the producer must produce a value first, the consumer correctly consumes only after the producer writes a value and the producer correctly produces the next value (after the first) only after the consumer reads the previous (or first) value. `ArrayBlockingQueue` stores the shared mutable data in an array, the size of which is specified as `ArrayBlockingQueue`'s constructor argument. An `ArrayBlockingQueue` is fixed in size and will not expand

to accommodate extra elements.

Class BlockingBuffer

Figures 23.14–23.15 demonstrate a `Producer` and a `Consumer` accessing an `ArrayBlockingQueue`. Class `BlockingBuffer` (Fig. 23.14) uses an `ArrayBlockingQueue` object that stores an `Integer` (line 6). Line 9 creates the `ArrayBlockingQueue` and passes 1 to the constructor so that the object holds a single value to mimic the `UnsynchronizedBuffer` example in Fig. 23.12. We discuss *multiple-element buffers* in Section 23.8. Because our `BlockingBuffer` class uses the *thread-safe* `ArrayBlockingQueue` class to manage all of its shared state (the shared buffer in this case), `BlockingBuffer` is itself *thread safe*, even though we have not implemented the synchronization ourselves.

```
1  // Fig. 23.14: BlockingBuffer.java
2  // Creating a synchronized buffer using an Array
3  import java.util.concurrent.ArrayBlockingQueue;
4
5  public class BlockingBuffer implements Buffer {
6      private final ArrayBlockingQueue<Integer> buf
7
8      public BlockingBuffer() {
9          buffer = new ArrayBlockingQueue<Integer>(1
10              }
11
12      // place value into buffer
13      @Override
14      public void blockingPut(int value) throws Int
```

```

15         buffer.put(value); // place value in buffer
16         System.out.printf("%s%2d\t%s%d\n", "Produc
17             "Buffer cells occupied: ", buffer.size(
18                 }
19
20         // return value from buffer
21         @Override
22     public int blockingGet() throws InterruptedEx
23         int readValue = buffer.take(); // remove v
24         System.out.printf("%s %2d\t%s%d\n", "Consu
25         readValue, "Buffer cells occupied: ", b
26
27         return readValue;
28     }
29 }

```

Fig. 23.14

Creating a synchronized buffer using an
ArrayBlockingQueue.

BlockingBuffer implements interface Buffer (Fig. 23.10 modified to remove line 24) and Consumer (Fig. 23.11 modified to remove line 24) from the example in Section 23.5. This approach demonstrates encapsulated synchronization—the threads accessing the shared object are unaware that their buffer accesses are now synchronized. The synchronization is handled entirely in the `blockingPut` and `blockingGet` methods of `BlockingBuffer` by calling the synchronized `ArrayBlockingQueue` methods `put` and `take`, respectively. Thus, the `Producer` and `Consumer`

`Runnable`s are properly synchronized simply by calling the shared object's `blockingPut` and `blockingGet` methods.

Line 15 in method `blockingPut` (Fig. 23.14) calls the `ArrayBlockingQueue` object's `put` method. This method call blocks if necessary until there's room in the `buffer` to place the `value`. Method `blockingGet` calls the `ArrayBlockingQueue` object's `take` method (line 23). This method call *blocks* if necessary until there's an element in the `buffer` to remove. Lines 16–17 and 24–25 use the `ArrayBlockingQueue` object's `size` method to display the total number of elements currently in the `ArrayBlockingQueue`.

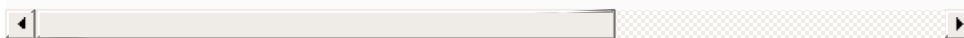
Class BlockingBufferTest

Class `BlockingBufferTest` (Fig. 23.15) contains the `main` method that launches the application. Line 11 creates an `ExecutorService`, and line 14 creates a `BlockingBuffer` object and assigns its reference to the `Buffer` variable `sharedLocation`. Lines 16–17 execute the `Producer` and `Consumer` `Runnable`s. Line 19 calls method `shutdown` to end the application when the threads finish executing the `Producer` and `Consumer` tasks, and line 20 waits for the scheduled tasks to complete.

```

2 // Two threads manipulating a blocking buffer tha
3 // implements the producer/consumer relationship.
4 import java.util.concurrent.ExecutorService;
5 import java.util.concurrent.Executors;
6 import java.util.concurrent.TimeUnit;
7
8 public class BlockingBufferTest {
9     public static void main(String[] args) throws
10         // create new thread pool
11         ExecutorService executorService = Executor
12
13         // create BlockingBuffer to store ints
14         Buffer sharedLocation = new BlockingBuffer
15
16         executorService.execute(new Producer(share
17         executorService.execute(new Consumer(share
18
19         executorService.shutdown();
20         executorService.awaitTermination(1, TimeUn
21     }
22 }

```



Producer writes	1	Buffer cells occupied: 1
Consumer reads	1	Buffer cells occupied: 0
Producer writes	2	Buffer cells occupied: 1
Consumer reads	2	Buffer cells occupied: 0
Producer writes	3	Buffer cells occupied: 1
Consumer reads	3	Buffer cells occupied: 0
Producer writes	4	Buffer cells occupied: 1
Consumer reads	4	Buffer cells occupied: 0
Producer writes	5	Buffer cells occupied: 1
Consumer reads	5	Buffer cells occupied: 0

Producer writes	6	Buffer cells occupied: 1
Consumer reads	6	Buffer cells occupied: 0
Producer writes	7	Buffer cells occupied: 1
Consumer reads	7	Buffer cells occupied: 0
Producer writes	8	Buffer cells occupied: 1
Consumer reads	8	Buffer cells occupied: 0
Producer writes	9	Buffer cells occupied: 1
Consumer reads	9	Buffer cells occupied: 0
Producer writes	10	Buffer cells occupied: 1

Producer done producing Terminating Producer

Consumer reads 10	Buffer cells occupied: 0
-------------------	--------------------------

Consumer read values totaling 55 Terminating Consumer
--

Fig. 23.15

Two threads manipulating a blocking buffer that properly implements the producer/consumer relationship.

While methods put and take of ArrayBlockingQueue

are properly synchronized, `BlockingBuffer` methods `blockingPut` and `blockingGet` (Fig. 23.14) are not declared to be synchronized. Thus, the statements performed in method `blockingPut`—the `put` operation (Fig. 23.14, line 15) and the output (lines 16–17)—are *not atomic*; nor are the statements in method `blockingGet`—the `take` operation (line 23) and the output (lines 24–25). So there's no guarantee that each output will occur immediately after the corresponding `put` or `take` operation, and the outputs may appear out of order. Even if they do, the `ArrayBlockingQueue` object is properly synchronizing access to the data, as evidenced by the fact that the sum of values read by the consumer is always correct.