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# Mastering ArduinoJson 6

Efficient JSON serialization for embedded C++



THIRD EDITION

# Contents

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# Chapter 4

## Serializing with ArduinoJson

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*Any fool can write code that a computer can understand.  
Good programmers write code that humans can understand.*

– Martin Fowler, Refactoring: Improving the Design of Existing Code

## 4.1 The example of this chapter

Reading a JSON document is only half of the story; we'll now see how to write a JSON document with ArduinoJson.

In the previous chapter, we played with GitHub's API. We'll use a very different example for this chapter: pushing data to Adafruit IO.

Adafruit IO is a cloud storage service for IoT data. They have a free plan with the following restrictions:

- 30 data points per minute
- 30 days of data storage
- 5 feeds

If you need more, it's just \$10 a month. The service is very easy to use. All you need is an Adafruit account (yes, you can use the account from the Adafruit shop).

As we did in the previous chapter, we'll start with a simple JSON document and add complexity step by step.

Since Adafruit IO doesn't impose a secure connection, we can use a less powerful microcontroller than in the previous chapter; we'll use an Arduino UNO with an Ethernet Shield.



## 4.2 Creating an object

### 4.2.1 The example

Here is the JSON object we want to create:

```
{
  "value": 42,
  "lat": 48.748010,
  "lon": 2.293491
}
```

It's a flat object, meaning that it has no nested object or array, and it contains the following members:

1. "value" is an integer that we want to save in Adafruit IO.
2. "lat" is the latitude coordinate.
3. "lon" is the longitude coordinate.

Adafruit IO supports other optional members (like the elevation coordinate and the time of measurement), but the three members above are sufficient for our example.

### 4.2.2 Allocating the JsonDocument

As for the deserialization, we start by creating a `JsonDocument` to hold the memory representation of the object. The previous chapter introduced `JsonDocument`, so I'll assume that you're now familiar with it.

As you recall, a `JsonDocument` has a fixed capacity which we must set on creation. Here, we have one object with no nested values, so the size is `JSON_OBJECT_SIZE(3)`. For a more complex document, you can use the [ArduinoJson Assistant](#) to compute the required capacity.

We saw that `JsonDocument` comes in two flavors: `StaticJsonDocument`, which lives in the stack, and `DynamicJsonDocument`, which resides in the heap. In this case, we can use a `StaticJsonDocument` because the document is small, and I never use the heap on AVR anyway. Indeed, the Arduino UNO has only 2KB of RAM, so we can't afford any heap

fragmentation. If you don't know which implementation of `JsonDocument` to choose for your project, consult the ArduinoJson Assistant.

Here is the code:

```
const int capacity = JSON_OBJECT_SIZE(3);  
StaticJsonDocument<capacity> doc;
```

The `JsonDocument` is currently empty and `JsonDocument::isNull()` returns `true`. If we serialized it now, the output would be `"null"`.

### 4.2.3 Adding members

An empty `JsonDocument` automatically becomes an object when we add members to it. We do that with the subscript operator (`[]`), just like we did in the previous chapter:

```
doc["value"] = 42;  
doc["lat"] = 48.748010;  
doc["lon"] = 2.293491;
```

The memory usage is now `JSON_OBJECT_SIZE(3)`, so the `JsonDocument` is full. When the `JsonDocument` is full, so it cannot accept any new member. If you try to add another value, the operation will fail and set the flag `JsonDocument::overflowed()` to `true`. To actually add more values, you must create a larger `JsonDocument`.

### 4.2.4 Alternative syntax

Most of the time `JsonDocument::overflowed()` is enough, but ArduinoJson provides an alternative syntax that allows you to check whether the insertion succeed. Here is the equivalent of the previous snippet:

```
doc["value"].set(42);  
doc["lat"].set(48.748010);  
doc["lon"].set(2.293491);
```

The compiler generates the same executable as with the previous syntax, except that `JsonVariant::set()` returns `true` for success or `false` on failure.

To be honest, I never check if insertion succeeds in my programs. The reason is simple: the JSON document is roughly the same for each iteration; if it works once, it always works. There is no reason to bloat the code for a situation that cannot happen.

### 4.2.5 Creating an empty object

We just saw that the `JsonDocument` becomes an object as soon as you insert a member, but what if you don't have any members to add? What if you want to create an empty object?

When you need an empty object, you cannot rely on the implicit conversion anymore. Instead, you must explicitly convert the `JsonDocument` to a `JsonObject` with `JsonDocument::to<JsonObject>()`:

```
// Convert the document to an object
JsonObject obj = doc.to<JsonObject>();
```

This function clears the `JsonDocument`, so all existing references become invalid. Then, it creates an empty object at the root of the document and returns a reference to this object.

At this point, the `JsonDocument` is not empty anymore and `JsonDocument::isNull()` returns `false`. If we serialized this document, the output would be `"{}"`.

### 4.2.6 Removing members

It's possible to erase a member from an object by calling `JsonObject::remove(key)`. However, for reasons that will become clear in [chapter 6](#), this function doesn't release the memory in the `JsonDocument`.

The `remove()` function is a frequent cause of bugs because it creates a memory leak. Indeed, if you add and remove members in a loop, the `JsonDocument` grows, but memory is never released.

### 4.2.7 Replacing members

It's possible to replace a member in the object, for example:

```
obj["value"] = 42;  
obj["value"] = 43;
```

Most of the time, replacing a member doesn't require a new allocation in the `JsonDocument`. However, it can cause a memory leak if the old value has associated memory, for example, if the old value is a string, an array, or an object.



#### Memory leaks

Replacing and removing values produce a memory leak inside the `JsonDocument`.

In practice, this problem only happens in programs that use a `JsonDocument` to store the application's state, which is not the purpose of `ArduinoJson`. Let's be clear; the sole purpose of `ArduinoJson` is to serialize and deserialize JSON documents.

Be careful not to fall into this common anti-pattern, and make sure you read the [case studies](#) to see how `ArduinoJson` should be used.



## 4.3 Creating an array

### 4.3.1 The example

Now that we can create objects, let's see how to create an array. Our new example will be an array that contains two objects.

```
[
  {
    "key": "a1",
    "value": 12
  },
  {
    "key": "a2",
    "value": 34
  }
]
```

The values `12` and `34` are just placeholder; in reality, we'll use the result from `analogRead()`.

### 4.3.2 Allocating the `JsonDocument`

As usual, we start by computing the capacity of the `JsonDocument`:

- There is one array with two elements: `JSON_ARRAY_SIZE(2)`
- There are two objects with two members: `2*JSON_OBJECT_SIZE(2)`

Here is the code:

```
const int capacity = JSON_ARRAY_SIZE(2) + 2*JSON_OBJECT_SIZE(2);
StaticJsonDocument<capacity> doc;
```

### 4.3.3 Adding elements

In the previous section, we saw that an empty `JsonDocument` automatically becomes an object as soon as we insert the first member. This statement was only partially correct: it becomes an object as soon as we use it as an object.

Indeed, if we treat an empty `JsonDocument` as an array, it automatically becomes an array. For example, this happens if we call `JsonDocument::add()`, like so:

```
doc.add(1);  
doc.add(2);
```

After these two lines, the `JsonDocument` contains `[1,2]`.

Alternatively, we can create the same array with the `[]` operator, like so:

```
doc[0] = 1;  
doc[1] = 2;
```

However, this second syntax is a little slower because it requires walking the list of members. Use this syntax to *replace* elements and use `add()` to add elements to the array.

Now that we can create an array, let's rewind a little because that's not the JSON array we want: instead of two integers, we need two nested objects.

### 4.3.4 Adding nested objects

To add the nested objects to the array, we call `JsonArray::createNestedObject()`. This function creates a nested object, appends it to the array, and returns a reference.

Here is how to create our sample document:

```
JsonObject obj1 = doc.createNestedObject();  
obj1["key"] = "a1";  
obj1["value"] = analogRead(A1);  
  
JsonObject obj2 = doc.createNestedObject();  
obj2["key"] = "a2";  
obj2["value"] = analogRead(A2);
```

Alternatively, we can create the same document like so:

```
doc[0]["key"] = "a1";  
doc[0]["value"] = analogRead(A1);  
  
doc[1]["key"] = "a2";  
doc[1]["value"] = analogRead(A2);
```

Again, this syntax is slower because it needs to walk the list, so only use it for small documents.

### 4.3.5 Creating an empty array

We saw that the `JsonDocument` becomes an array as soon as we add elements, but this doesn't allow creating an empty array. If we want to create an empty array, we need to convert the `JsonDocument` explicitly with `JsonDocument::to<JsonArray>()`:

```
// Convert the JsonDocument to an array  
JsonArray arr = doc.to<JsonArray>();
```

Now the `JsonDocument` contains `[]`.

As we already saw, `JsonDocument::to<T>()` clears the `JsonDocument`, so it also invalidates all previously acquired references.

### 4.3.6 Replacing elements

As for objects, it's possible to replace elements in arrays using `JsonArray::operator[]`:

```
arr[0] = 666;  
arr[1] = 667;
```

Most of the time, replacing the value doesn't require a new allocation in the `JsonDocument`. However, if some memory was held by the previous value (a `JsonObject`, for example), this memory is not released. It's a limitation of `ArduinoJson`'s memory allocator, as we'll see later in this book.

### 4.3.7 Removing elements

As for objects, you can remove an element from the array, with `JsonArray::remove()`:

```
arr.remove(0);
```

As I said, `remove()` doesn't release the memory from the `JsonDocument`, so you should never call this function in a loop.

## 4.4 Writing to memory

We saw how to construct an array. Now, it's time to serialize it into a JSON document. There are several ways to do that. We'll start with a JSON document in memory.

We could use a `String`, but as you know, I prefer avoiding dynamic memory allocation. Instead, we'd use a good old `char[]`:

```
// Declare a buffer to hold the result
char output[128];
```

### 4.4.1 Minified JSON

To produce a JSON document from a `JsonDocument`, we simply need to call `serializeJson()`:

```
// Produce a minified JSON document
serializeJson(doc, output);
```

After this call, the string `output` contains:

```
[{"key": "a1", "value": 12}, {"key": "a2", "value": 34}]
```

As you see, there are neither space nor line breaks; it's a "minified" JSON document.

### 4.4.2 Specifying (or not) the buffer size

If you're a C programmer, you may have been surprised that I didn't provide the buffer size to `serializeJson()`. Indeed, there is an overload of `serializeJson()` that takes a `char*` and a size:

```
serializeJson(doc, output, sizeof(output));
```

However, that's not the overload we called in the previous snippet. Instead, we called a template method that infers the size of the buffer from its type (in this case, `char[128]`).

Of course, this shorter syntax only works because `output` is an array. If it were a `char*` or a variable-length array, we would have had to specify the size.



### Variable-length array

A variable-length array, or VLA, is an array whose size is unknown at compile time. Here is an example:

```
void f(int n) {  
    char buf[n];  
    // ...  
}
```

C99 and C11 allow VLAs, but not C++. However, some compilers support VLAs as an extension.

This feature is often criticized in C++ circles, but Arduino users seem to love it. That's why ArduinoJson supports VLAs in all functions that accept a string.

## 4.4.3 Prettified JSON

The minified version is what you use to store or transmit a JSON document because the size is optimal. However, it's not very easy to read. Humans prefer “prettified” JSON documents with spaces and line breaks.

To produce a prettified document, you must use `serializeJsonPretty()` instead of `serializeJson()`:

```
// Produce a prettified JSON document  
serializeJsonPretty(doc, output);
```

Here is the content of `output`:

```
[  
  {  
    "key": "a1",  
    "value": 12  
  },  
  {
```

```
"key": "a2",  
"value": 34  
}  
]
```

Of course, you need to make sure that the output buffer is big enough; otherwise, the JSON document will be incomplete.

#### 4.4.4 Measuring the length

ArduinoJson allows computing the length of the JSON document before producing it. This information is helpful for:

1. allocating an output buffer,
2. reserving the size on disk, or
3. setting the `Content-Length` header.

There are two methods, depending on the type of document you want to produce:

```
// Compute the length of the minified JSON document  
int len1 = measureJson(doc);  
  
// Compute the length of the prettified JSON document  
int len2 = measureJsonPretty(doc);
```

In both cases, the result doesn't count the null-terminator.

By the way, `serializeJson()` and `serializeJsonPretty()` return the number of bytes they wrote. The results are the same as `measureJson()` and `measureJsonPretty()`, except if the output buffer is too small.



##### Avoid prettified documents

With the example above, the sizes are 73 and 110. In this case, the prettified version is only 50% bigger because the document is simple, but in most cases, the ratio is largely above 100%.

Remember, we're in an embedded environment: every byte counts, and so does every CPU cycle. Always prefer a minified version.

### 4.4.5 Writing to a String

The functions `serializeJson()` and `serializeJsonPretty()` have overloads taking a `String`:

```
String output = "JSON = ";  
serializeJson(doc, output);
```

The behavior is slightly different: the JSON document is appended to the `String`; it doesn't replace it. That means the above snippet sets the content of the output variable to:

```
JSON = [{"key": "a1", "value": 12}, {"key": "a2", "value": 34}]
```

This behavior seems inconsistent? That's because `ArduinoJson` treats `String` like a stream; more on that later.

### 4.4.6 Casting a `JsonVariant` to a `String`

You should remember from the chapter on deserialization that we must cast `JsonVariant` to the type we want to read.

It is also possible to cast a `JsonVariant` to a `String`. If the `JsonVariant` contains a string, the return value is a copy of the string. However, if the `JsonVariant` contains something else, the returned string is a serialization of the variant.

We could rewrite the previous example like this:

```
// Cast the JsonDocument to a string  
String output = "JSON = " + doc.as<String>();
```

This trick works with `JsonDocument` and `JsonVariant`, but not with `JsonArray` and `JsonObject` because they don't have an `as<T>()` function.



## 4.5 Writing to a stream

### 4.5.1 What's an output stream?

For now, every JSON document we produced remained in memory, but that's usually not what we want. In many situations, it's possible to send the JSON document directly to its destination (whether it's a file, a serial port, or a network connection) without any copy in RAM.

We saw in the previous chapter what an “input stream” is, and we saw that Arduino represents this concept with the `Stream` class. Similarly, there are “output streams,” which are sinks of bytes. We can write to an output stream, but we cannot read. In the Arduino land, an output stream is materialized by the `Print` class.

Here are examples of classes derived from `Print`:

Library	Class	Well known instances
Core	<code>HardwareSerial</code>	<code>Serial</code> , <code>Serial1</code> ...
ESP	<code>BluetoothSerial</code>	<code>SerialBT</code>
	<code>File</code>	
	<code>WiFiClient</code>	
	<code>WiFiClientSecure</code>	
Ethernet	<code>EthernetClient</code>	
	<code>EthernetUDP</code>	
GSM	<code>GSMClient</code>	
LiquidCrystal	<code>LiquidCrystal</code>	
SD	<code>File</code>	
SoftwareSerial	<code>SoftwareSerial</code>	
WiFi	<code>WiFiClient</code>	
Wire	<code>TwoWire</code>	<code>Wire</code>



#### `std::ostream`

In the C++ Standard Library, an output stream is represented by the `std::ostream` class.

ArduinoJson supports both `Print` and `std::ostream`.



### Performance issues

`serializeJson()` writes bytes one by one to the output stream, which can result in bad performances with unbuffered streams like `WiFiClient` or `File`. We'll see a simple workaround in the next chapter.

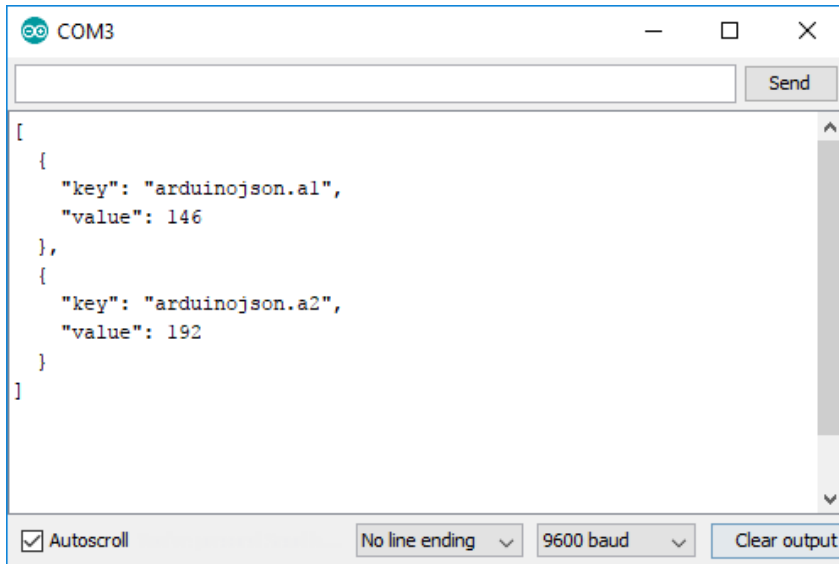
## 4.5.2 Writing to the serial port

The most famous implementation of `Print` is `HardwareSerial`, which is the class of `Serial`. To serialize a `JsonDocument` to the serial port of your Arduino, just pass `Serial` to `serializeJson()`:

```
// Print a minified JSON document to the serial port
serializeJson(doc, Serial);

// Same with a prettified document
serializeJsonPretty(doc, Serial);
```

You can see the result in the Arduino Serial Monitor, which is very handy for debugging.



If you want to send JSON documents between two boards, I recommend using `Serial1` for the communication link and keeping `Serial` for the debugging link. Of course, this

requires that your board has several UART, which is not the case of the UNO, so we would have to upgrade to a Leonardo (an excellent board, by the way).

Alternatively, you can use `Wire` for the communication link; but you must know that the `Wire` library limits the size of a message to 32 bytes (but there is a workaround for longer messages).

In theory, `SoftwareSerial` could also serve as the communication link, but I highly recommend against it because it's completely unreliable.

### 4.5.3 Writing to a file

Similarly, we can use a `File` instance as the target of `serializeJson()` and `serializeJsonPretty()`. Here is an example with the SD library:

```
// Open file for writing
File file = SD.open("adafruit.txt", FILE_WRITE);

// Write a prettified JSON document to the file
serializeJsonPretty(doc, file);
```

You can find the complete source code for this example in the `WriteSdCard` folder of the zip file provided with the book.

You can apply the same technique to write a file on SPIFFS or LittleFS, as we'll see [in the case studies](#).

### 4.5.4 Writing to a TCP connection

We're now reaching our goal of sending our measurements to Adafruit IO.

As I said in the introduction, we'll suppose that our program runs on an Arduino UNO with an Ethernet shield. Because the Arduino UNO has only 2KB of RAM, we'll not use the heap at all. As I said, I never use the heap on processors with so little RAM because I cannot afford any fragmentation.

### Preparing the Adafruit IO account

If you want to run this program, you need an account on Adafruit IO (a free account is sufficient). Then, you need to copy your user name and your “AIO key” to the source code.

```
#define IO_USERNAME "bblanchon"  
#define IO_KEY "aio_iCpP41N5k8yoZStMrh2US1A0hNAu"
```

We'll include the AIO key in an HTTP header, and it will authenticate our program on Adafruit's server:

```
X-AIO-Key: aio_iCpP41N5k8yoZStMrh2US1A0hNAu
```

Finally, you need to create a “group” named “arduinojson” in your Adafruit IO account. In this group, you need to create two feeds: “a1” and “a2.”

### The request

To send our measured samples to Adafruit IO, we have to send a POST request to `http://io.adafruit.com/api/v2/bblanchon/groups/arduinojson/data`, and include the following JSON document in the body:

```
{  
  "location": {  
    "lat": 48.748010,  
    "lon": 2.293491  
  },  
  "feeds": [  
    {  
      "key": "a1",  
      "value": 42  
    },  
    {  
      "key": "a2",  
      "value": 43  
    }  
  ]  
}
```

```
}
```

As you see, it's a little more complex than our previous example because the array is not at the root of the document. Instead, the array is nested in an object under the key "feeds".

Let's review the HTTP request before jumping to the code:

```
POST /api/v2/bblanchon/groups/arduinojson/data HTTP/1.1
Host: io.adafruit.com
Connection: close
Content-Length: 103
Content-Type: application/json
X-AIO-Key: aio_iCpP41N5k8yoZStMrh2US1AOhNAu

{"location":{"lat":48.748010,"lon":2.293491},"feeds":[{"key":"a1",...
```

### The code

OK, time for action! We'll open a TCP connection to `io.adafruit.com` using an `EthernetClient`, and we'll send the request. As far as `ArduinoJson` is concerned, there are very few changes compared to the previous examples because we can pass the `EthernetClient` as the target of `serializeJson()`. We'll call `measureJson()` to set the value of the `Content-Length` header.

Here is the code:

```
// Allocate JsonDocument
const int capacity = JSON_ARRAY_SIZE(2) + 4 * JSON_OBJECT_SIZE(2);
StaticJsonDocument<capacity> doc;

// Add the "location" object
JsonObject location = doc.createNestedObject("location");
location["lat"] = 48.748010;
location["lon"] = 2.293491;

// Add the "feeds" array
JsonArray feeds = doc.createNestedArray("feeds");
```

```
JsonObject feed1 = feeds.createNestedObject();
feed1["key"] = "a1";
feed1["value"] = analogRead(A1);
JsonObject feed2 = feeds.createNestedObject();
feed2["key"] = "a2";
feed2["value"] = analogRead(A2);

// Connect to the HTTP server
EthernetClient client;
client.connect("io.adafruit.com", 80);

// Send "POST /api/v2/bblanchon/groups/arduinojson/data HTTP/1.1"
client.println("POST /api/v2/" IO_USERNAME
              "/groups/arduinojson/data HTTP/1.1");

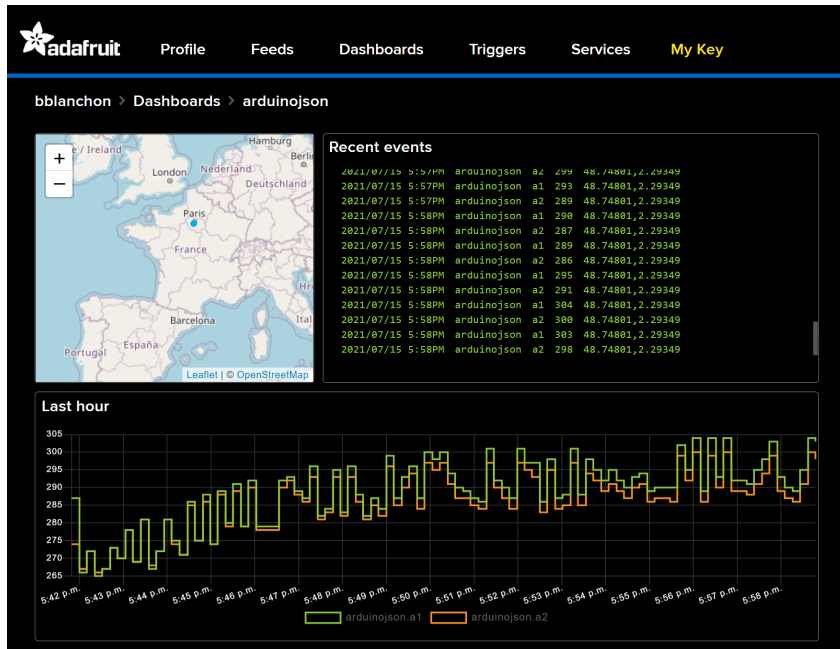
// Send the HTTP headers
client.println("Host: io.adafruit.com");
client.println("Connection: close");
client.print("Content-Length: ");
client.println(measureJson(doc));
client.println("Content-Type: application/json");
client.println("X-AIO-Key: " IO_KEY);

// Terminate headers with a blank line
client.println();

// Send JSON document in body
serializeJson(doc, client);
```

You can find the complete source code of this example in the `AdafruitIo` folder of the zip file. This code includes the necessary error checking that I removed from the manuscript for clarity.

Below is a picture showing the results on the Adafruit IO dashboard.



## 4.6 Duplication of strings

Depending on the type, ArduinoJson stores strings either by pointer or by copy. If the string is a `const char*`, it stores a pointer; otherwise, it makes a copy. This feature reduces memory consumption when you use string literals.

String type	Storage
<code>const char*</code>	pointer
<code>char*</code>	copy
<code>String</code>	copy
<code>const __FlashStringHelper*</code>	copy

As usual, the copy lives in the `JsonDocument`, so you may need to increase its capacity depending on the type of string you use.

ArduinoJson will store only one copy of each string, a feature called “string deduplication”. For example, if you insert the string `"hello"` multiple times, the `JsonDocument` will only keep one copy.

### 4.6.1 An example

Compare this program:

```
// Create the array ["value1","value2"]
doc.add("value1");
doc.add("value2");

// Print the memory usage
Serial.println(doc.memoryUsage()); // 16
```

with the following:

```
// Create the array ["value1","value2"]
doc.add(String("value1"));
doc.add(String("value2"));

// Print the memory usage
```



```
Serial.println(doc.memoryUsage()); // 30
```

They both produce the same JSON document, but the second one requires much more memory because ArduinoJson copies the strings. If you run these programs on an ATmega328, you'll see 16 for the first and 30 for the second. On an ESP8266, it would be 32 and 46.

### 4.6.2 Keys and values

The duplication rules apply equally to keys and values. In practice, we mostly use string literals for keys, so they are rarely duplicated. String values, however, often originate from variables and then entail string duplication.

Here is a typical example:

```
String identifier = getIdentifier();  
doc["id"] = identifier; // "id" is stored by pointer  
                       // identifier is copied
```

Again, the duplication occurs for any type of string except `const char*`.

### 4.6.3 Copy only occurs when adding values

In the example above, ArduinoJson copied the `String` because it needed to add it to the `JsonDocument`. On the other hand, if you use a `String` to extract a value from a `JsonDocument`, it doesn't make a copy.

Here is an example:

```
// The following line produces a copy of "key"  
doc[String("key")] = "value";  
  
// The following line produces no copy  
const char* value = doc[String("key")];
```

### 4.6.4 ArduinoJson Assistant to the rescue

As we saw in the previous chapter, the Assistant shows the number of bytes required to duplicate the strings of the document.

The screenshot shows the ArduinoJson Assistant web interface. At the top, there's a navigation bar with links to Documentation, Assistant, Troubleshooter, Book, and News. A search bar is also present. Below the navigation bar, the title "ArduinoJson Assistant" is displayed, followed by a brief description: "The ArduinoJson Assistant is an online tool that computes the required `JsonDocument` capacity for a given document and generates a sample program."

The main content area is divided into four steps: 1. Configuration, 2. JSON, 3. Size, and 4. Program. The current step is "Step 3: Size".

Under "Step 3: Size", there's a table showing memory requirements:

Category	Value	Description
Data structures	1040	Bytes needed to store the JSON objects and arrays in memory
Strings	175	Bytes needed to store the strings in memory
Total (minimum)	1215	Minimum capacity for the <code>JsonDocument</code> .
Total (recommended)	1536	Including some slack in case the strings change, and rounded to a power of two

Below the table, there's a section for "Tweaks (advanced users only)". It includes two dropdown menus for "Store floating point values as" (set to "float (default)") and "Store integral values values as" (set to "long (default)"). Below these, there are three checkboxes:

- ☐ Assume values are `const char*`  
JsonDocument stores strings differently depending on their types. It stores `const char*` by pointer (which takes no extra space) and all other types by copy. Check this box if you're only adding `const char*` values.
- ☒ Assume keys are `const char*`  
Same as above but for keys. Uncheck this box if your program generates keys at runtime.
- ☐ Deduplicate values when measuring the capacity  
ArduinoJson detects duplicate strings to store only one copy, but you can tell the Assistant to include all strings. You should uncheck this box if you used placeholders values (like XXXX) in the box above.

At the bottom of the "Tweaks" section, there are "Previous" and "Next: Program" buttons.

At the very bottom of the page, there's a footer with information about ArduinoJson, a newsletter sign-up form, and links to About, Contact, and Privacy pages.

In practice, the actual size may differ from what the Assistant predicts because it doesn't know which strings need to be copied and which don't. By default, it assumes it must store keys by pointer and values by copy. Moreover, it doesn't deduplicate the values, in case you repeated the same placeholder several times in your sample input.

You can change the Assistant behavior by expanding the "Tweaks" section at the bottom of step 3, as shown in the picture above. You can choose the storage type (pointer or

copy) for keys and values. You can also enable or disable deduplication. The changes are instantly reflected into the “Strings” row of the table so that you can see the effect of each setting.

## 4.7 Inserting special values

Before finishing this chapter, let's see how we can insert special values in the JSON document.

### 4.7.1 Adding null

The first special value is `null`, which is a legal token in a JSON. There are several ways to add a `null` in a `JsonDocument`; here they are:

```
// Use a nullptr (requires C++11)
arr.add(nullptr);

// Use a null char-pointer
arr.add((char*)0);

// Use a null JsonArray, JsonObject, or JsonVariant
arr.add(JsonVariant());
```

### 4.7.2 Adding pre-formatted JSON

The other special value is a JSON string that is already formatted and that `ArduinoJson` should not treat as a regular string.

You can do that by wrapping the string with a call to `serialized()`:

```
// adds "[1,2]"
arr.add("[1,2]");

// adds [1,2]
arr.add(serialized("[1,2]"));
```

The program above produces the following JSON document:

```
[  
  "[1,2]",  
  [1,2]  
]
```

Use this feature when a part of the document cannot change; it will simplify your code and reduce the executable size. You can also use it to insert something that the library doesn't allow.

You can pass a Flash string or a `String` instance to `serialized()`, but its content will be copied into the `JsonDocument`. As usual, Flash strings must have the type `const __FlashStringHelper*` to be recognized as such.

## 4.8 Summary

In this chapter, we saw how to serialize a JSON document with ArduinoJson. Here are the key points to remember:

- Creating the document:
  - To add a member to an object, use the subscript operator (`[]`)
  - To append an element to an array, call `add()`
  - The first time you add a member to a `JsonDocument`, it automatically becomes an object.
  - The first time you append an element to a `JsonDocument`, it automatically becomes an array.
  - You can explicitly convert a `JsonDocument` with `JsonDocument::to<T>()`.
  - `JsonDocument::to<T>()` clears the `JsonDocument`, so it invalidates all previously acquired references.
  - `JsonDocument::to<T>()` return a reference to the root array or object.
  - To create a nested array or object, call `createNestedArray()` or `createNestedObject()`.
  - When you insert a string in a `JsonDocument`, it makes a copy, except if it's a `const char*`.
- Serializing the document:
  - To serialize a `JsonDocument`, call `serializeJson()` or `serializeJsonPretty()`.
  - To compute the length of the JSON document, call `measureJson()` or `measureJsonPretty()`.
  - `serializeJson()` appends to `String`, but it overrides the content of a `char*`.
  - You can pass an instance of `Print` (like `Serial`, `EthernetClient`, `WiFiClient`, or `File`) to `serializeJson()` to avoid a copy in the RAM.

In the next chapter, we'll see advanced techniques like filtering and logging.

## Continue reading...

---

That was a free chapter from “Mastering ArduinoJson”; the book contains seven chapters like this one. Here is what readers say:

This book is 100% worth it. Between solving my immediate problem in minutes, Chapter 2, and the various other issues this book made solving easy, **it is totally worth it**. I build software but I work in managed languages and for someone just getting started in C++ and embedded programming this book has been indispensable. — Nathan Burnett

I think the missing C++ course and the troubleshooting chapter **are worth the money by itself**. Very useful for C programming dinosaurs like myself. — Doug Petican

The short C++ section was a great refresher. The practical use of ArduinoJson in small embedded processors was just what I needed for my home automation work. **Certainly worth having!** Thank you for both the book and the library. — Douglas S. Basberg

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