

Embedded System Software





Software

Hardware

Software

```
graph TD; subgraph Software; Applications[Applications]; Libraries[Libraries]; OS[Operating System]; end; Hardware[Hardware];
```

Applications

Libraries

Operating System

Hardware

Software

```
graph TD; subgraph Software; Applications[Applications]; Libraries[Libraries]; OS[Operating System]; end; Hardware[Hardware];
```

Applications

Libraries

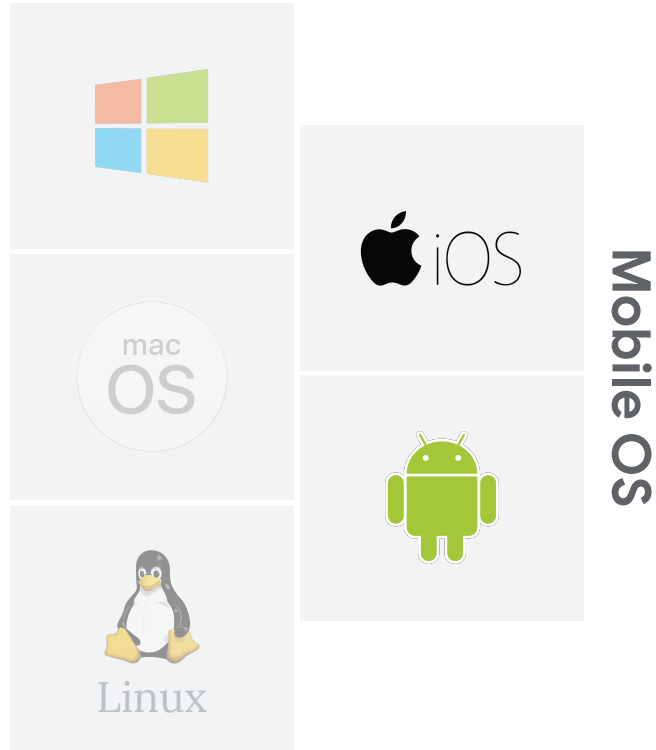
Operating System

Hardware

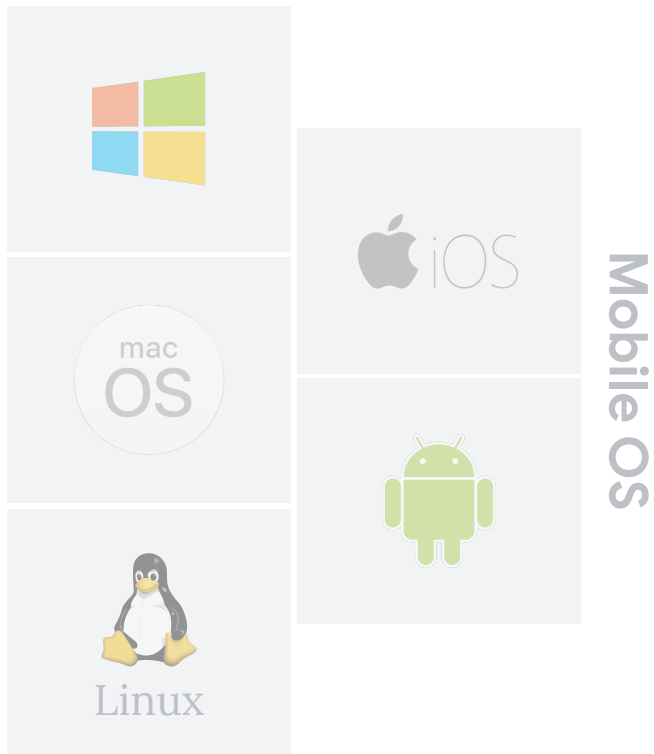
Widely Used Operating Systems



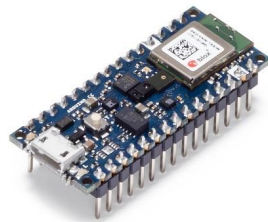
Widely Used Operating Systems



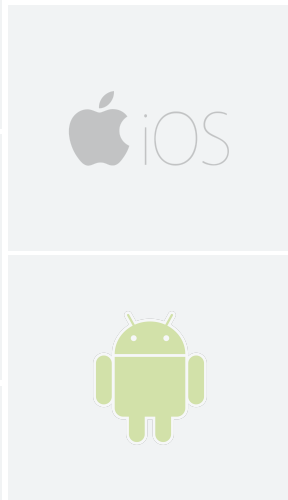
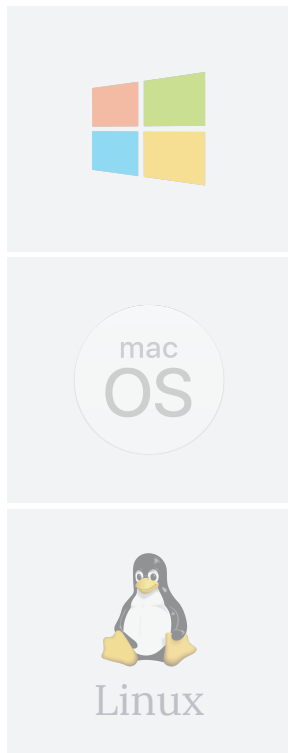
Widely Used Operating Systems



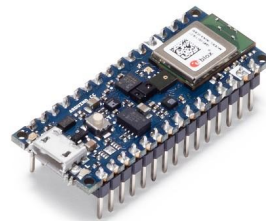
Embedded Systems



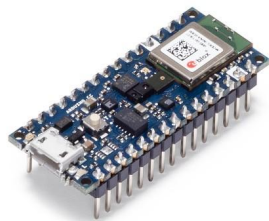
Widely Used Operating Systems



Mobile OS



Embedded Sys.



Blink | Arduino 1.8.5

✓ → 📄 ⬆ ⬇ 🔊

Blink § ▾

This example code is in the public domain.

<http://www.arduino.cc/en/Tutorial/Blink>

```
*/  
  
// the setup function runs once when you press reset or power the board  
void setup() {  
  // initialize digital pin LED_BUILTIN as an output.  
  pinMode(LED_BUILTIN, OUTPUT);  
}  
  
// the loop function runs over and over again forever  
void loop() {$  
  digitalWrite(LED_BUILTIN, HIGH); // turn the LED on (HIGH is the voltage level)  
  delay(1000); // wait for a second  
  digitalWrite(LED_BUILTIN, LOW); // turn the LED off by making the voltage LOW  
  delay(1000); // wait for a second  
}
```

32 Arduino/Genuino Uno on COM1



Software

Nano 33 BLE Sense
Hardware



The diagram illustrates a software stack. A large blue-outlined rectangle represents the 'Software' layer. Inside this rectangle, at the bottom, is a yellow rectangle labeled 'mbed OS'. Below the 'Software' container is a red rectangle labeled 'Nano 33 BLE Sense Hardware'.

Software

mbed OS

Nano 33 BLE Sense
Hardware

Software

Arduino

mbed OS

Nano 33 BLE Sense
Hardware

Software

TF Micro Application

Arduino

mbed OS

Nano 33 BLE Sense
Hardware

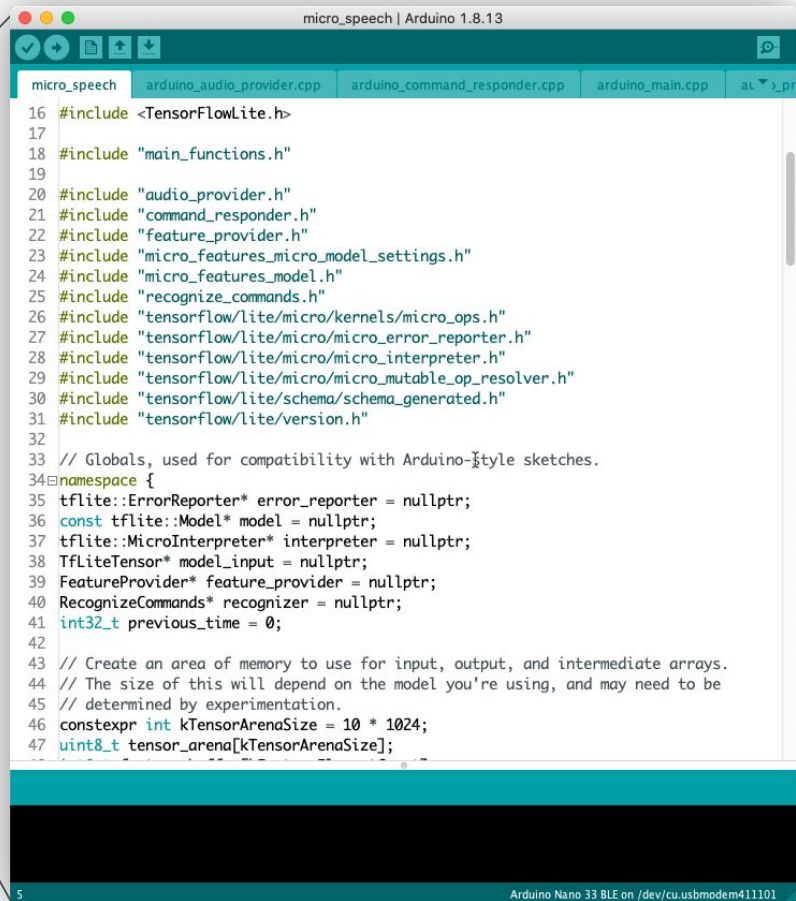
Software

TF Micro Application

Arduino

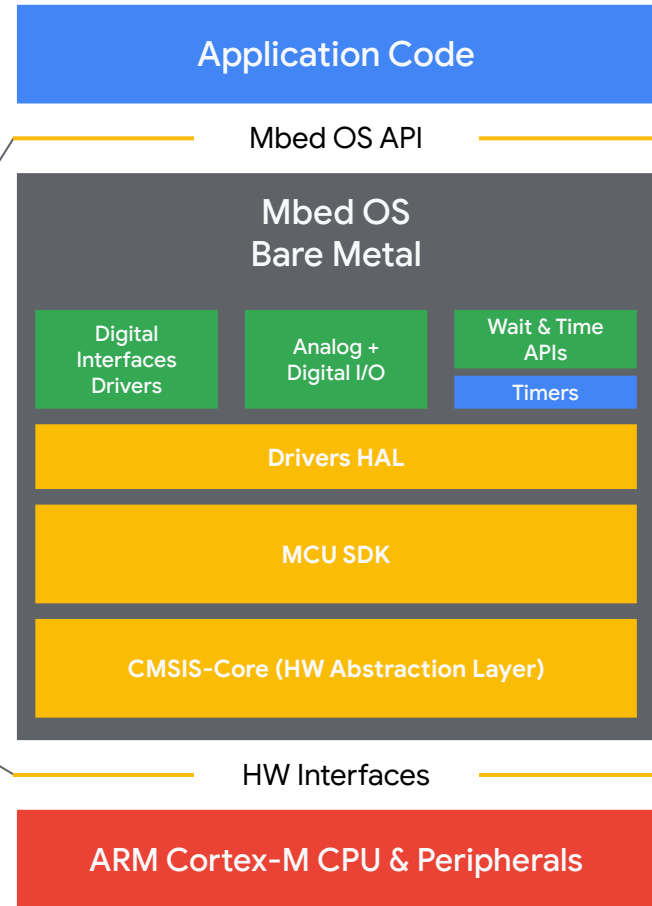
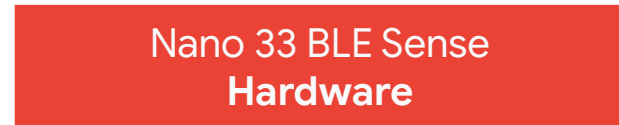
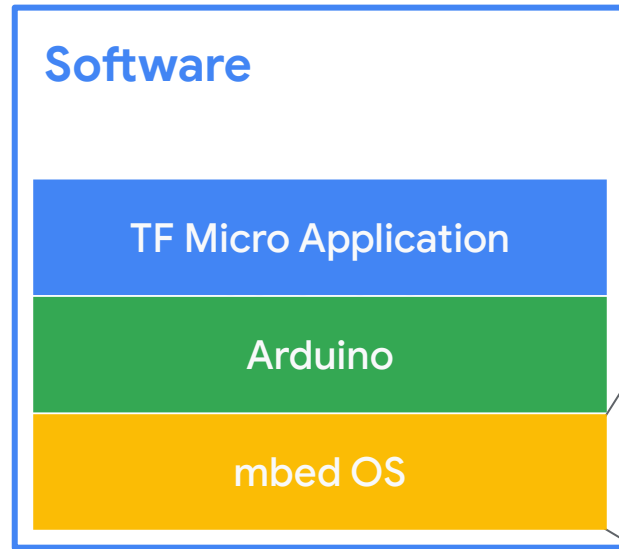
mbd OS

Nano 33 BLE Sense
Hardware



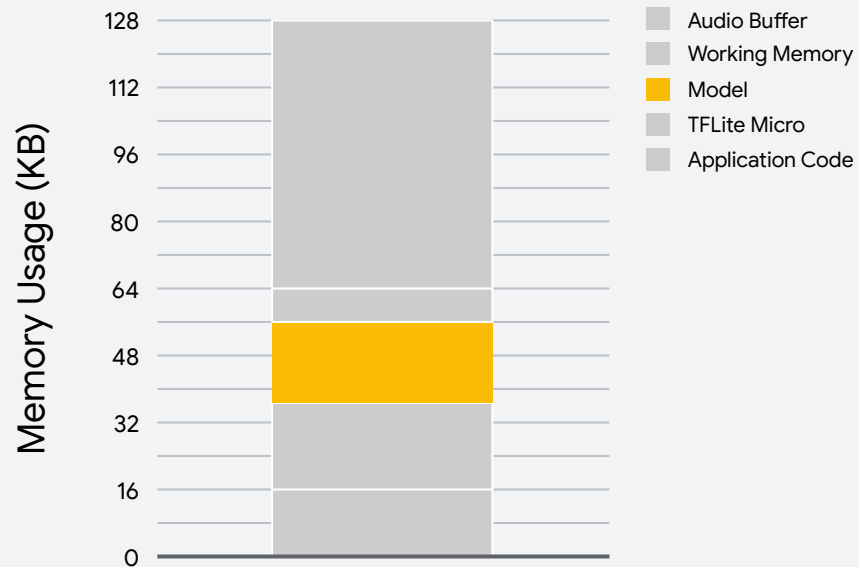
```
micro_speech | Arduino 1.8.13
micro_speech  arduino_audio_provider.cpp  arduino_command_responder.cpp  arduino_main.cpp  at_..._pr

16 #include <TensorFlowLite.h>
17
18 #include "main_functions.h"
19
20 #include "audio_provider.h"
21 #include "command_responder.h"
22 #include "feature_provider.h"
23 #include "micro_features_micro_model_settings.h"
24 #include "micro_features_model.h"
25 #include "recognize_commands.h"
26 #include "tensorflow/lite/micro/kernels/micro_ops.h"
27 #include "tensorflow/lite/micro/micro_error_reporter.h"
28 #include "tensorflow/lite/micro/micro_interpreter.h"
29 #include "tensorflow/lite/micro/micro_mutable_op_resolver.h"
30 #include "tensorflow/lite/schema/schema_generated.h"
31 #include "tensorflow/lite/version.h"
32
33 // Globals, used for compatibility with Arduino-style sketches.
34 namespace {
35   tflite::ErrorReporter* error_reporter = nullptr;
36   const tflite::Model* model = nullptr;
37   tflite::MicroInterpreter* interpreter = nullptr;
38   TfLiteTensor* model_input = nullptr;
39   FeatureProvider* feature_provider = nullptr;
40   RecognizeCommands* recognizer = nullptr;
41   int32_t previous_time = 0;
42
43   // Create an area of memory to use for input, output, and intermediate arrays.
44   // The size of this will depend on the model you're using, and may need to be
45   // determined by experimentation.
46   constexpr int kTensorArenaSize = 10 * 1024;
47   uint8_t tensor_arena[kTensorArenaSize];
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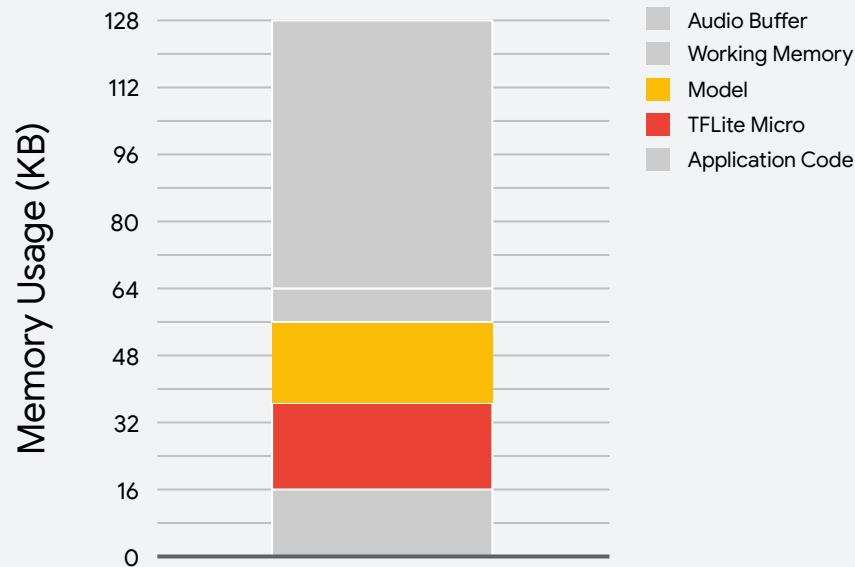
Memory Usage

- Need to be **resource aware**
- **Less** compute
- **Less** memory
- Use **quantization**



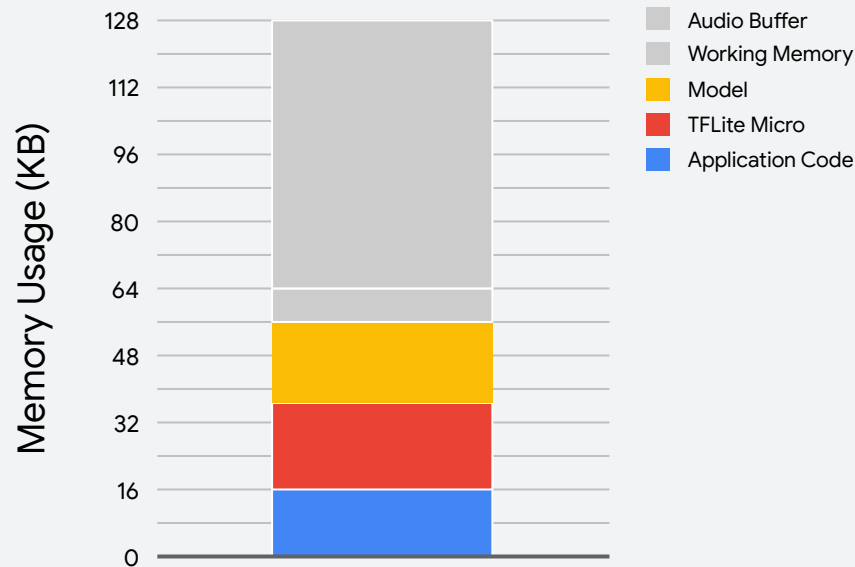
Memory Usage

- Need to be **resource aware**
- **Less** compute
- **Less** memory
- Use **quantization**



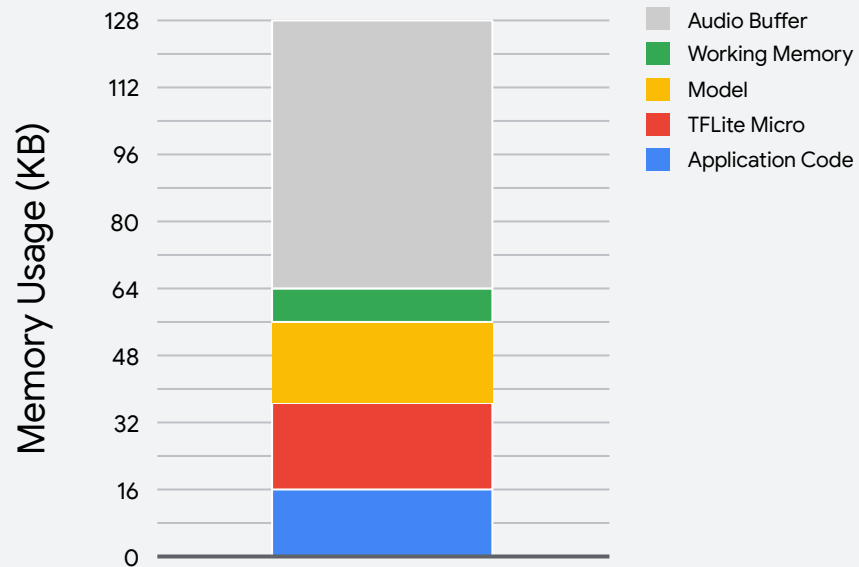
Memory Usage

- Need to be **resource aware**
- **Less** compute
- **Less** memory
- Use **quantization**



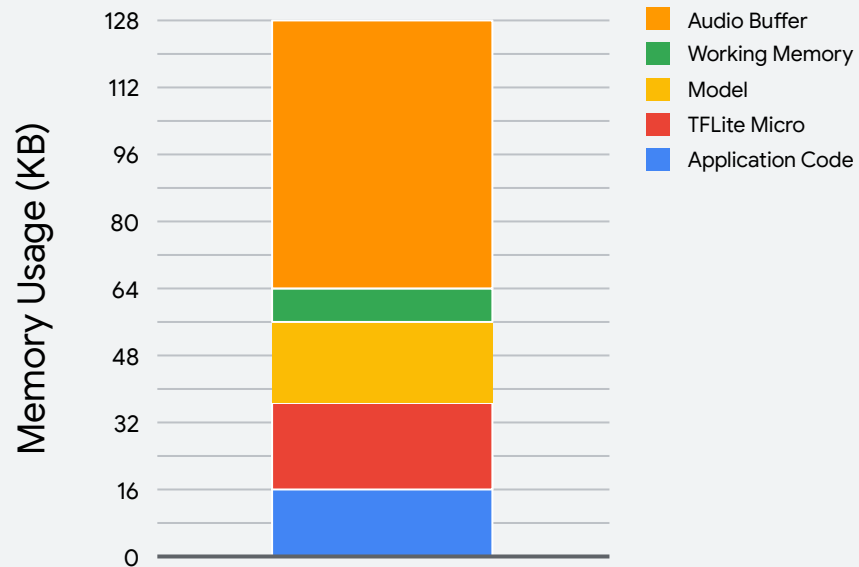
Memory Usage

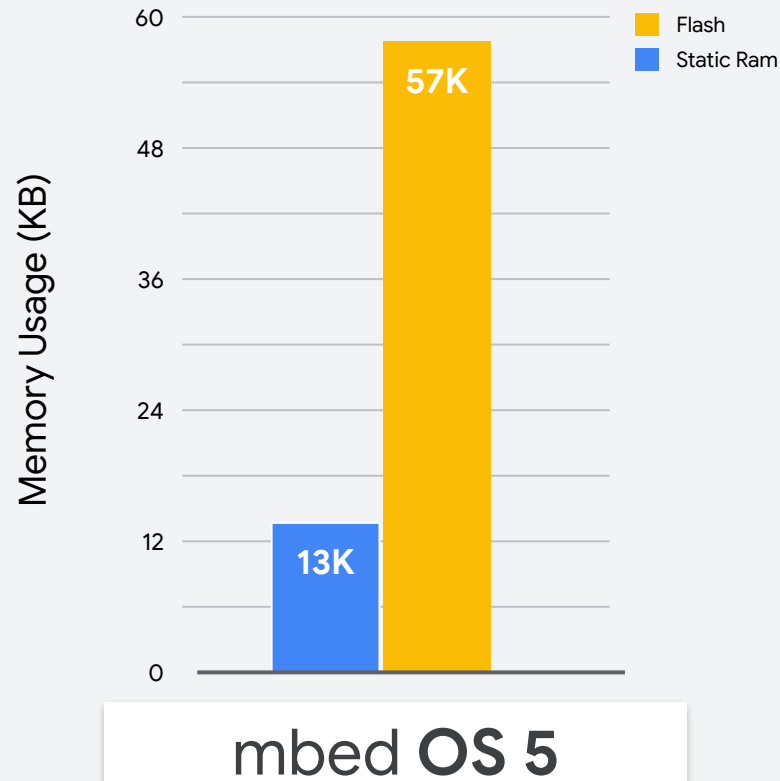
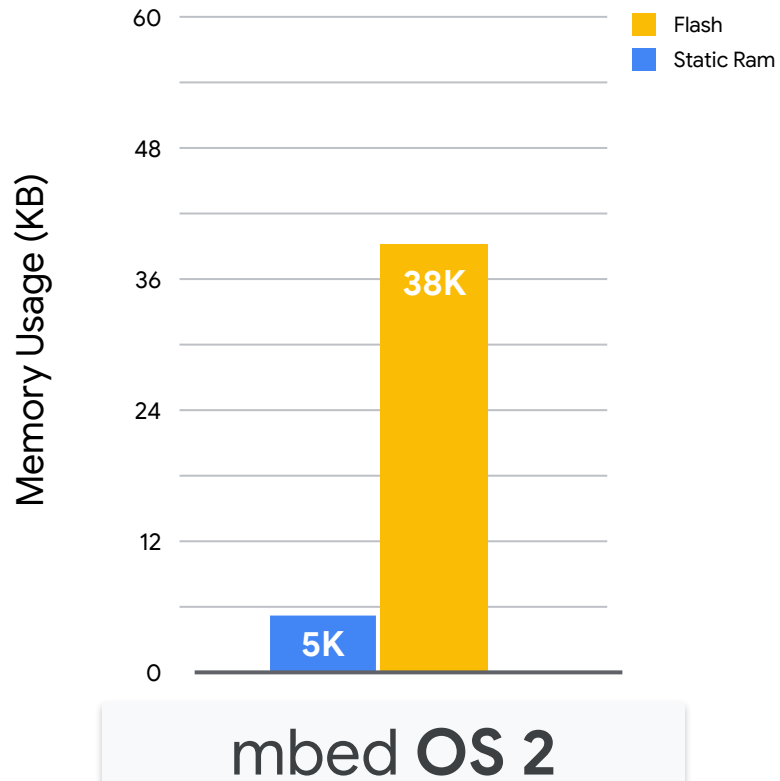
- Need to be **resource aware**
- **Less** compute
- **Less** memory
- Use **quantization**



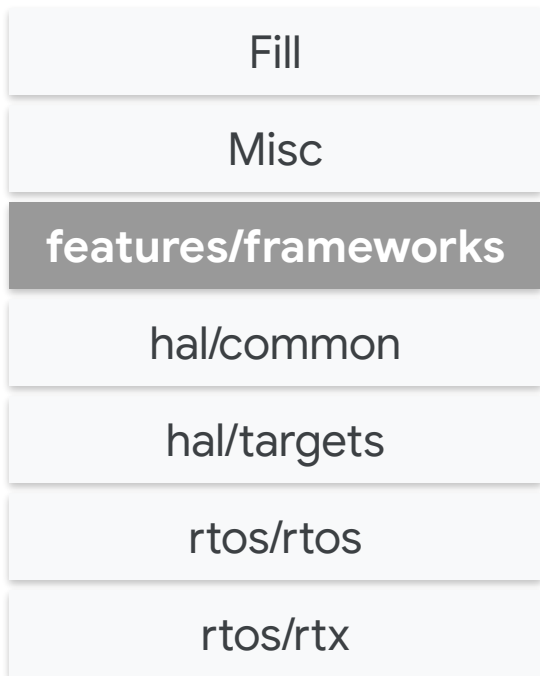
Memory Usage

- Need to be **resource aware**
- **Less** compute
- **Less** memory
- Use **quantization**



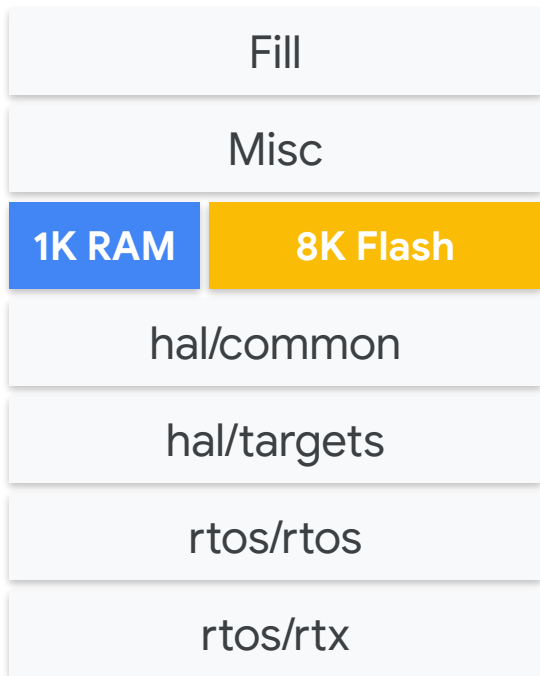


Removing Modules



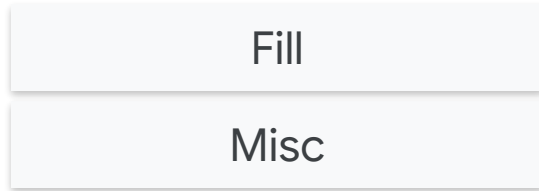
many unnecessary test tools
built in every binary

Removing Modules

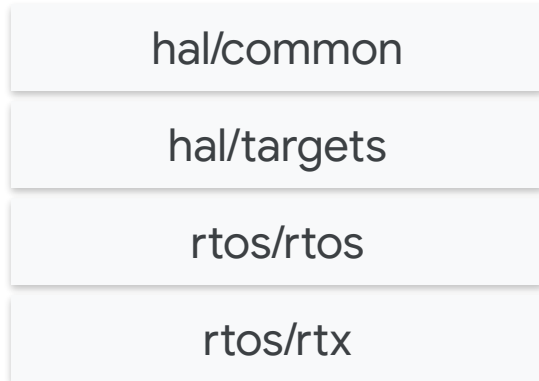


many unnecessary test tools
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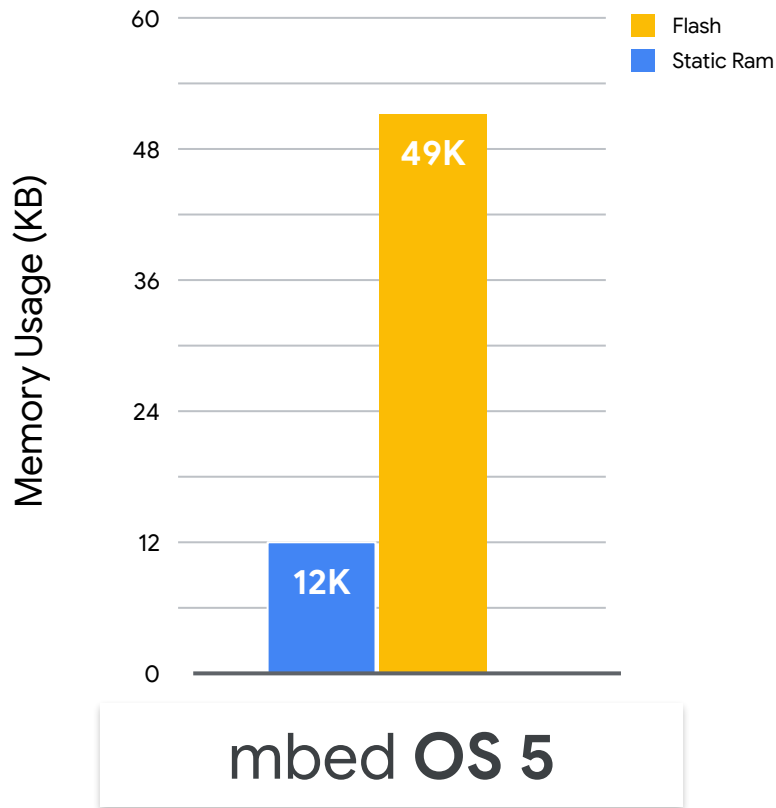
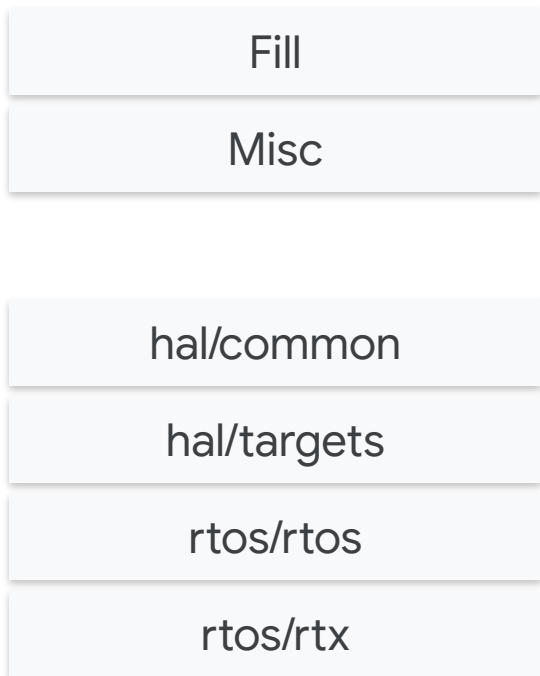
Removing Modules



————— **eliminate & save**



Removing Modules





TinyML is more than
just models