Making the Ada Drivers Library

Embedded Programming with Ada

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Programming is all about communication

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With:

- The compiler

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Programming is all about communication

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- The compiler
- The other tools (static analyzers, provers, etc.)
- Users of your API
- Your colleagues
- The idiot that wrote this stupid piece of code...
- **Oh, wait. It was me two months ago :(**

What makes Embedded Programming different?

Every bug costs more:

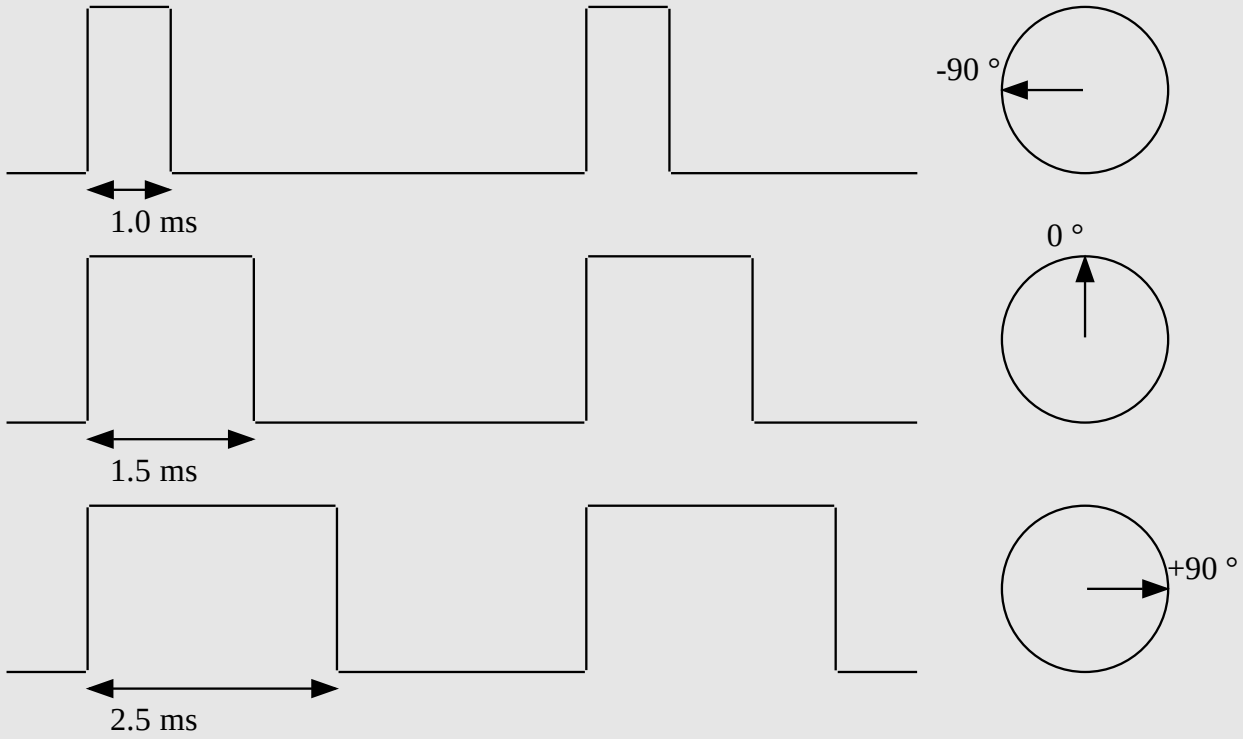
- More time to investigate
- More time to try a fix
- Potential destruction of hardware
- Updates are difficult

You need more control:

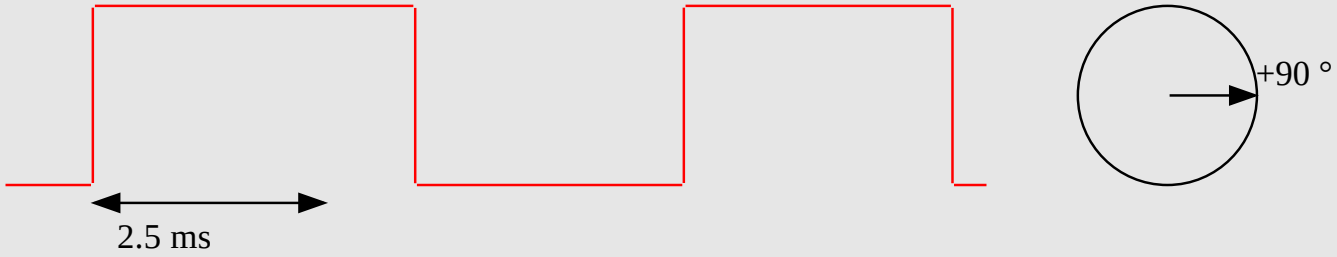
- Low resources (RAM, flash, CPU)
- Interaction with the hardware
- Real-Time constraints

Embedded Programming with Ada

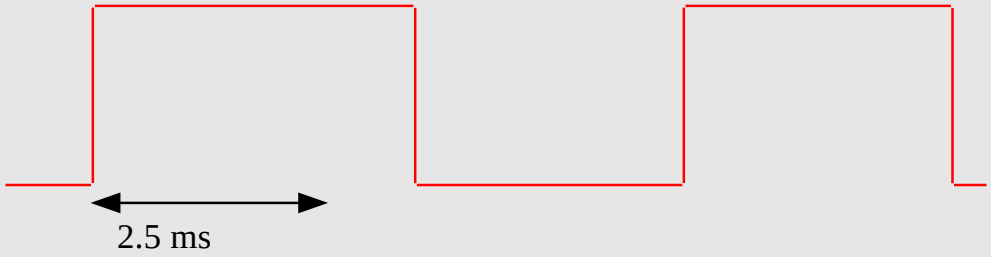
Servo motor example

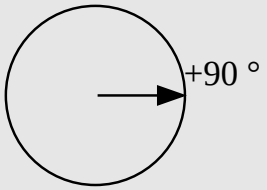


Servo motor example



Servo motor example





Types

```
procedure Set_Angle (Angle : Integer);
```

Types

```
--  Set desired angle for the servo motor
--
--  @param Angle: Desired rotation angle in degree.
--  Please do not use a value above 90 or below -90!
procedure Set_Angle (Angle : Integer);
```

Types

```
type Servo_Angle is range -90 .. 90;
--  Servo rotation angle in degree

procedure Set_Angle (Angle : Servo_Angle);
--  Set desired angle for the servo motor
```

The compiler: GNAT

```
Set_Angle (100);
```

```
warning: value not in range of type "Servo_Angle"
warning: "Constraint_Error" will be raised at run time
```

The static analyzer: CodePeer

```
procedure Set_Angle_Double (X : Servo_Angle) is
begin
   Set_Angle (X * 2);
end Set_Angle_Double;

Set_Angle_Double (80);
```

servo_driver.adb:27:4: high: precondition (range check) failure on call to servo_driver.set_angle_double: requires X in -45..45

The formal proof: SPARK

```
Phase 1 of 2: generation of Global contracts ...
servo_driver.adb:42:04: error in inlined body at line 23
servo_driver.adb:42:04: value not in range of type
   "Servo_Angle" defined at line 7
servo_driver.adb:42:04: "Constraint_Error" would have
   been raised at run time
```

The debugger: Gdb

```
(gdb) catch exception
Catchpoint 1: all Ada exceptions
(gdb) run

Catchpoint 1, CONSTRAINT_ERROR
   (servo_driver.adb:23 overflow check failed)
```

The code: Exception handling

```
procedure Set_Angle_Catch (X : Servo_Angle) is
begin

   Set_Angle (X * 2);

exception

   when Constraint_Error =>
      Put_Line ("Well, that was close");

end Set_Angle_Catch;
```

Your last chance

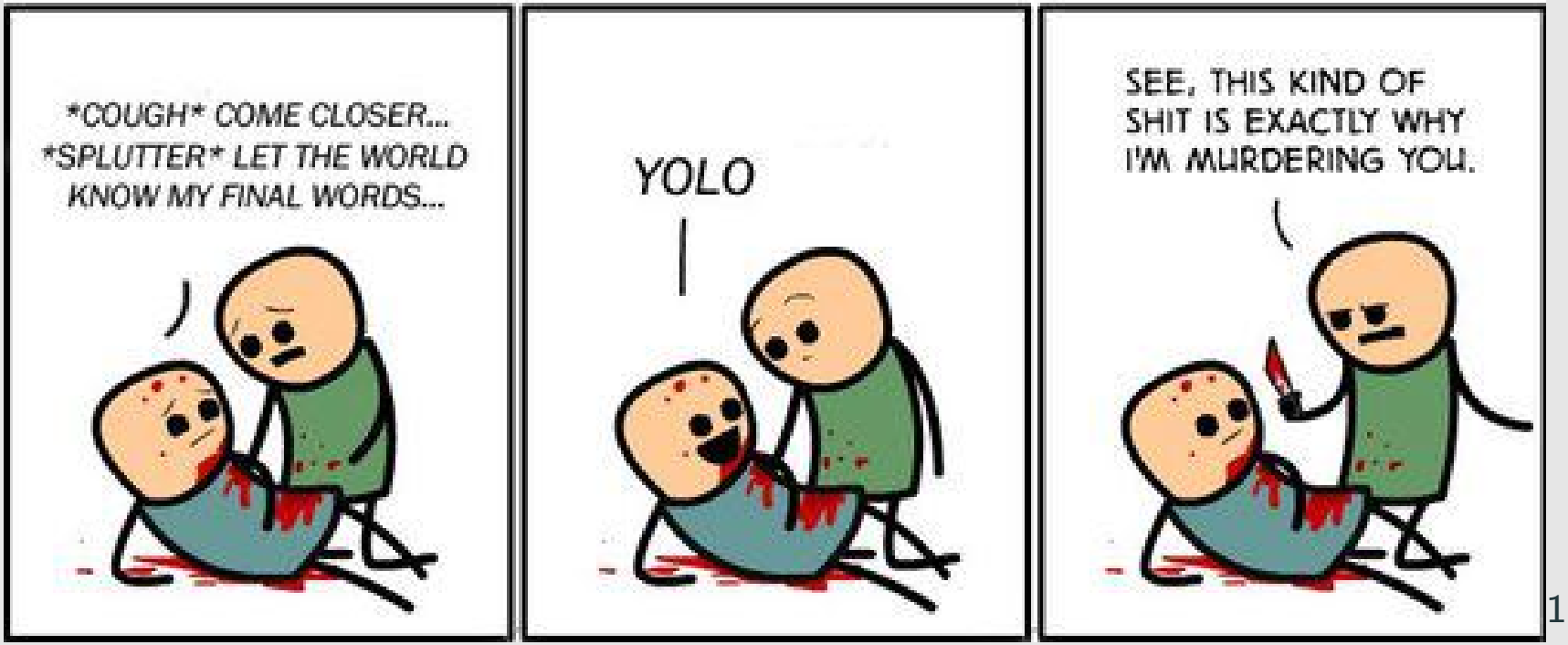
```
procedure Last_Chance_Handler is
begin

   --  Oops, there's something wrong

   Reset_The_Board;

end Last_Chance_Handler;
```

YOLO



[1]

[1] cyanide and happiness

Contracts

```
procedure Set_Angle (Angle : Servo_Angle)
   with Pre => Initialized;
--  Set desired angle for the servo motor

function Initialized return Boolean;
--  Return True if the driver is initialized

procedure Initialize
   with Post => Initialized;
--  Initialize the servo motor driver
```

Null access

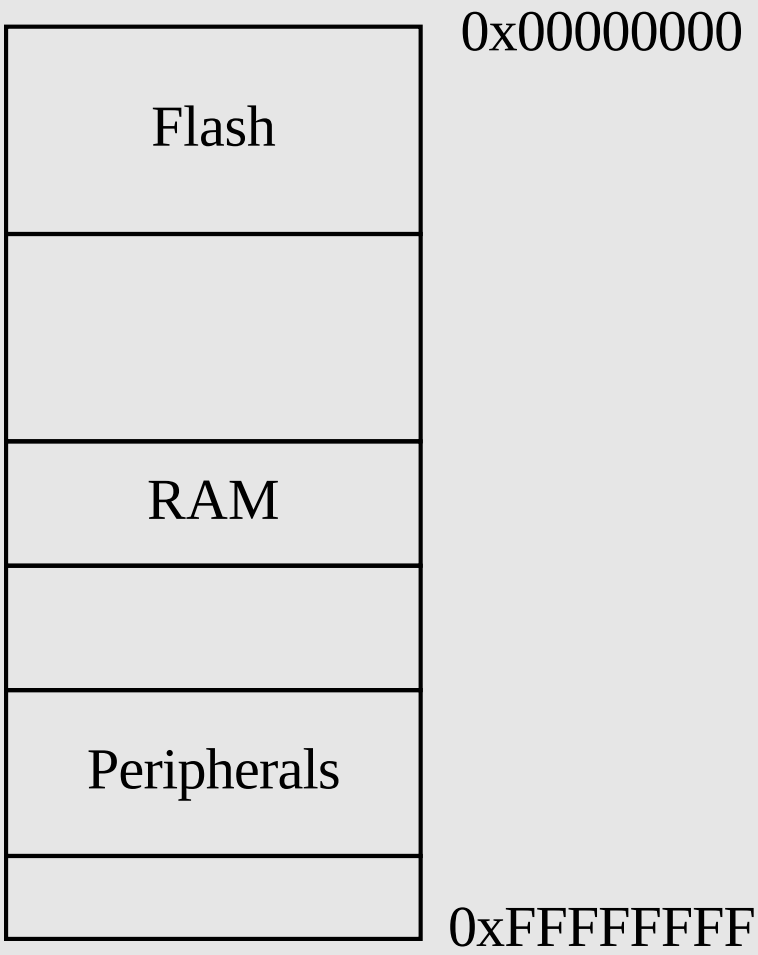
```
procedure Plop (Ptr : not null Some_Pointer);
```

Hardware mapping

```
--  High level view of the type
type Servo_Angle is range -90 .. 90

--  Hardware representation of the type
  with Size      => 8,
       Alignment => 16;
```

Memory mapped registers



Hardware mapping

7	6	5	4	3	2	1	0
Reserved		Sense		Reserved			

Sense: Pin sensing mechanism

- 0: Disabled
- 2: Sense for high level
- 3: Sense for low level

Hardware mapping

```
#define SENSE_MASK     (0x30)
#define SENSE_POS      (4)

#define SENSE_DISABLED (0)
#define SENSE_HIGH     (2)
#define SENSE_LOW      (3)

uint8_t *register = 0x80000100;

// Clear Sense field
*register &= ~SENSE_MASK;
// Set sense value
*register |= SENSE_DISABLED << SENSE_POS;
```

Hardware mapping

```
--  High level view of the Sense field
type Pin_Sense is
  (Disabled,
   High,
   Low)
  with Size => 2;

--  Hardware representation of the Sense field
for Pin_Sense use
  (Disabled => 0,
   High     => 2,
   Low      => 3);
```

Hardware mapping

```
--  High level view of the register
type IO_Register is record
   Reserved_A : UInt4;
   SENSE      : Pin_Sense;
   Reserved_B : UInt2;
end record;

--  Hardware representation of the register
for IO_Register use record
   Reserved_A at 0 range 0 .. 3;
   SENSE      at 0 range 4 .. 5;
   Reserved_B at 0 range 6 .. 7;
end record;
```

Hardware mapping

```
Register : IO_Register
  with Address => 16#8000_0100#;
```

```
Register.SENSE := Disabled;
```

SVD -> Ada

```
<field>
  <name>SENSE</name>
  <description>Pin sensing mechanism.</description>
  <lsb>16</lsb> <msb>17</msb>
  <enumeratedValues>
    <enumeratedValue>
      <name>Disabled</name>
      <description>Disabled.</description>
      <value>0x00</value>
    </enumeratedValue>
 [...]
```

github.com/AdaCore/svd2ada

Ravenscar Tasking

A.K.A There's a mini-RTOS in my language[2]

- Tasks (threads)
- Time handling
  - Clock
  - Delays
- Protected Objects:
  - Mutual exclusion
  - Synchronization between tasks
  - Interrupt handling

[2] blog.adacore.com/theres-a-mini-rtos-in-my-language

Task

```
task body My_Task is
   Next_Release : Time;
begin
   --  Set Initial release time
   Next_Release := Clock + Milliseconds (100);

   loop
      --  Suspend My_Task
      delay until Next_Release;

      --  Compute the next release time
      Next_Release := Next_Release + Milliseconds (100);

      --  Do something really cool at 10Hz...
   end loop;
end My_Task;
```

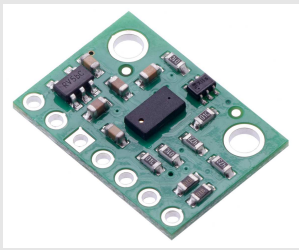
Making the Ada Drivers Library

Ada Drivers Library

- Firmware library
- Hardware and vendor independent
- 100% Ada
- Hosted on GitHub:
  `github.com/AdaCore/Ada_Drivers_Library`

Components

I2C, SPI, UART, etc.



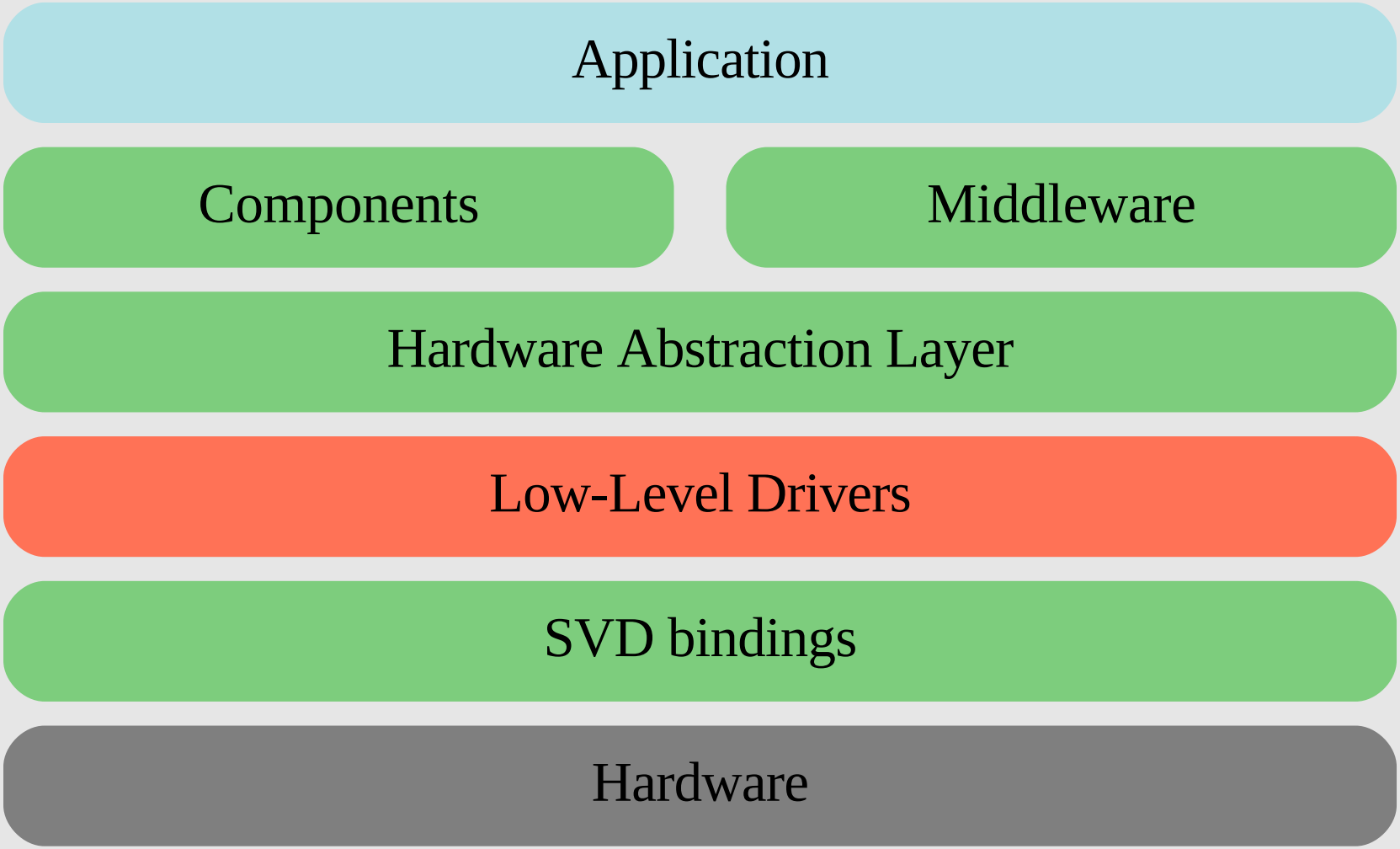
Supported components

- Audio DAC: SGTL5000, CS43L22, W8994
- Camera: OV2640, OV7725
- IO expander: MCP23XXX, STMPE1600, HT16K33
- Motion: AK8963, BNO055, L3GD20, LIS3DSH, MMA8653, MPU9250
- Range: VL53L0X
- LCD: ILI9341, OTM8009a, ST7735R, SSD1306
- Touch panel: FT5336, FT6X06, STMPE811
- Module:
  - AdaFruit's trellis
  - AdaFruit's Thermal printer

Middleware

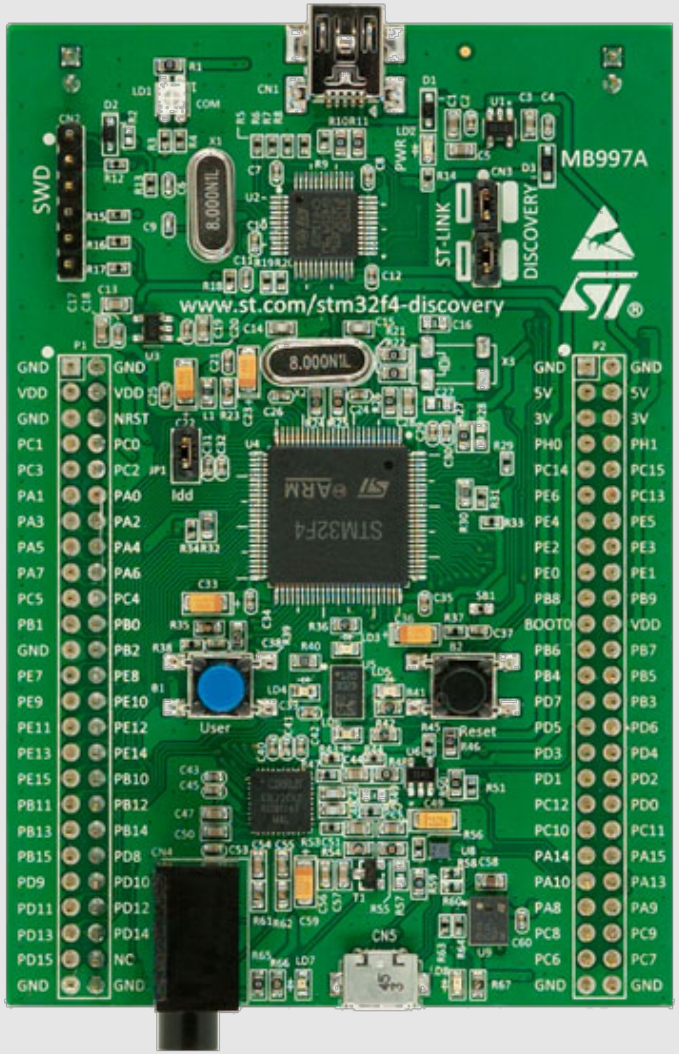
- Bitmap drawing
- File System: FAT and ARM semi-hosting
- Log utility

Architecture



Supported platforms

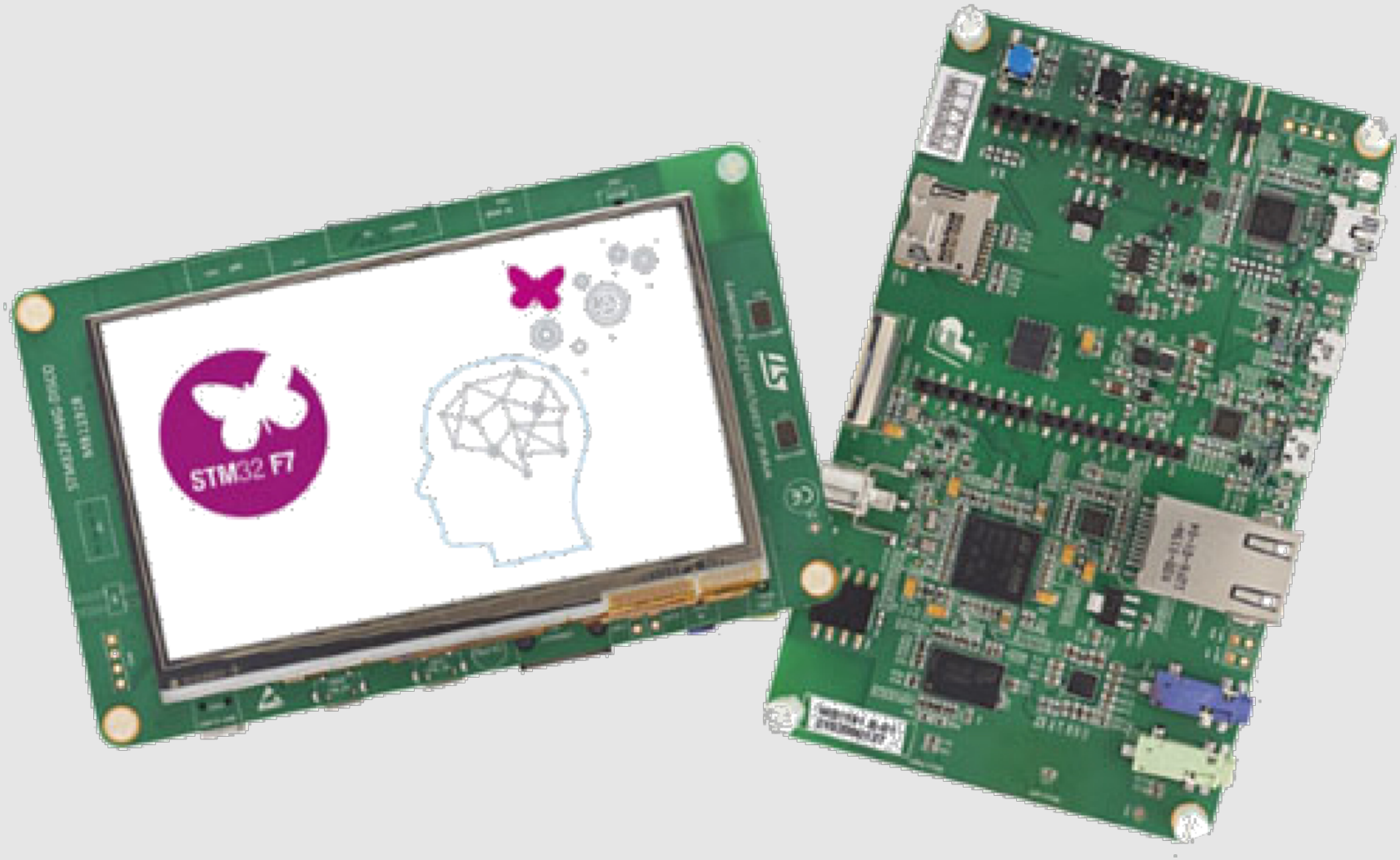
STM32F405 Discovery (ARM Cortex-M4F)



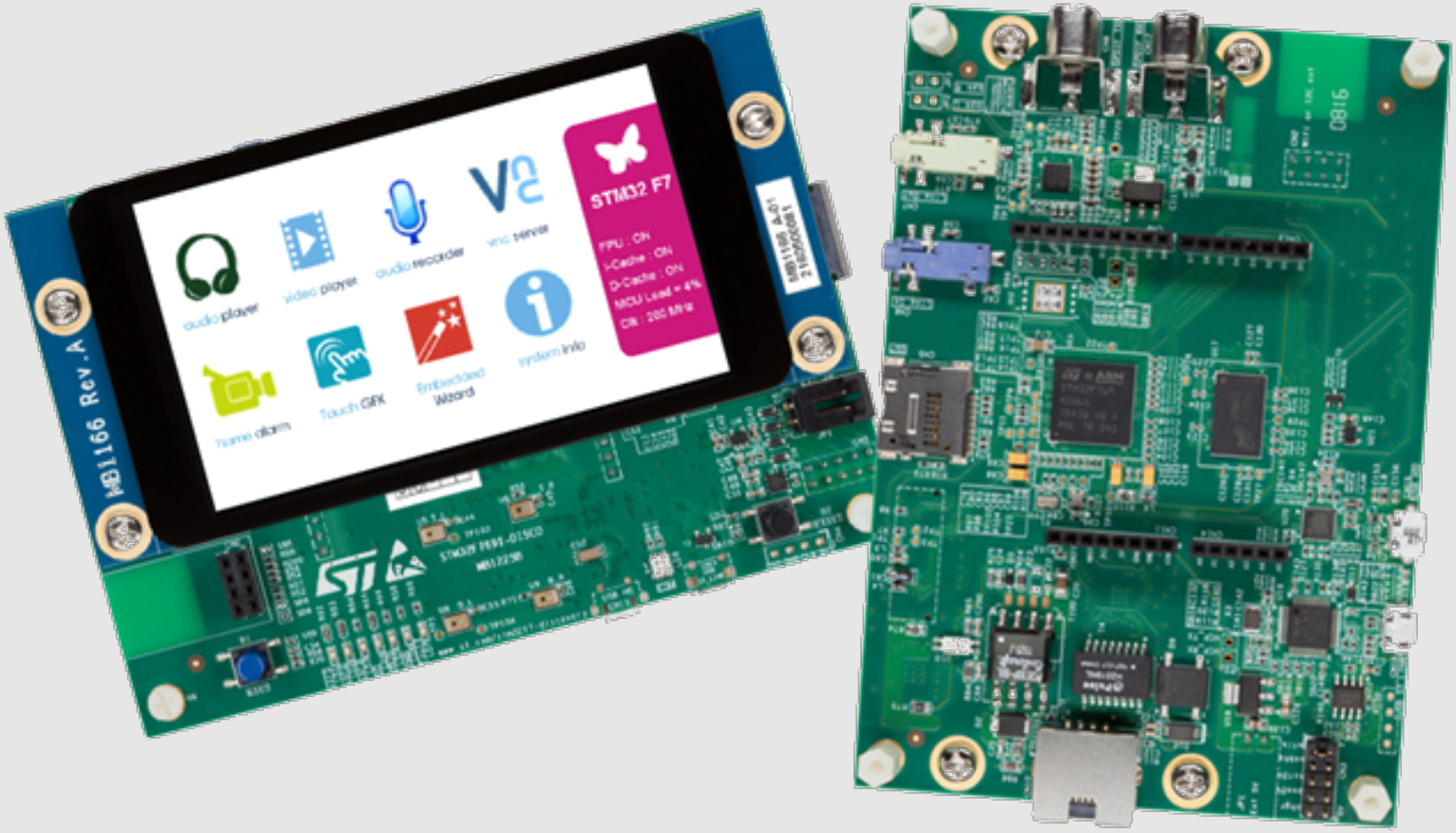
STM32F429 Discovery (ARM Cortex-M4F)

STM32F469 Discovery (ARM Cortex-M4F)

STM32F746 Discovery (ARM Cortex-M7F)



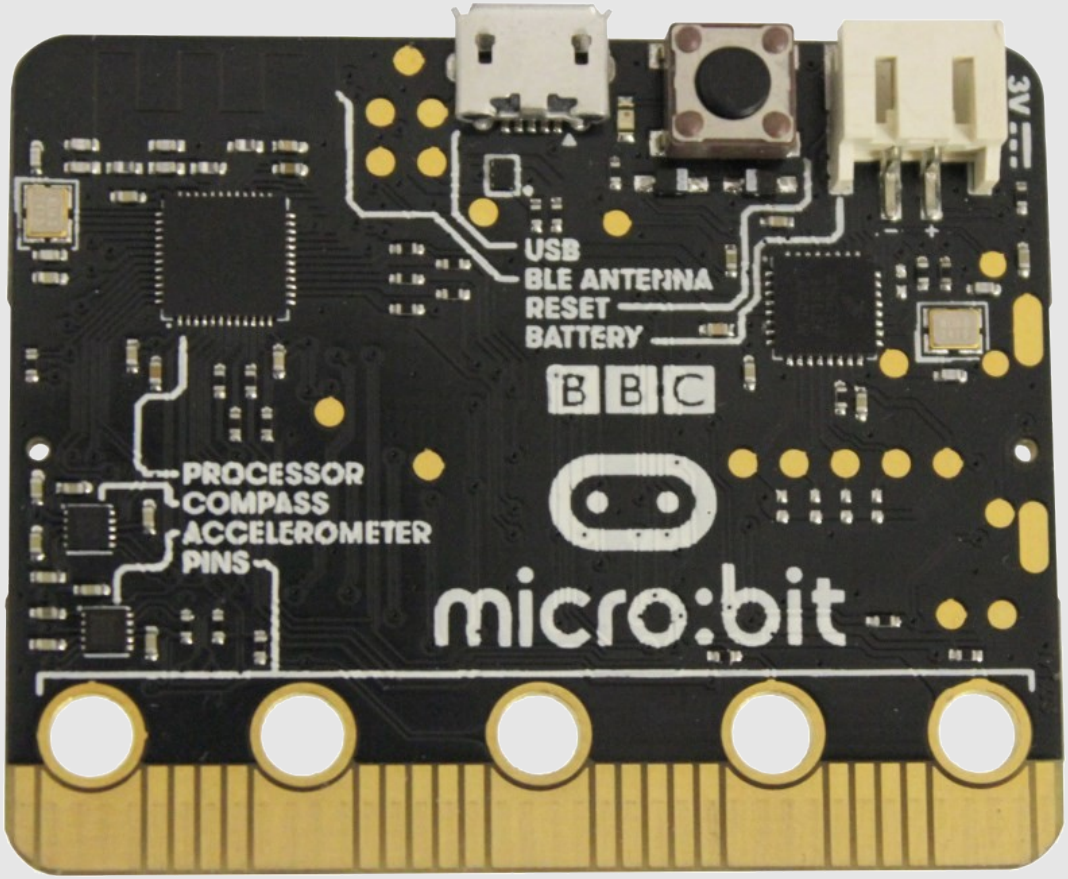
STM32F769 Discovery (ARM Cortex-M7F)



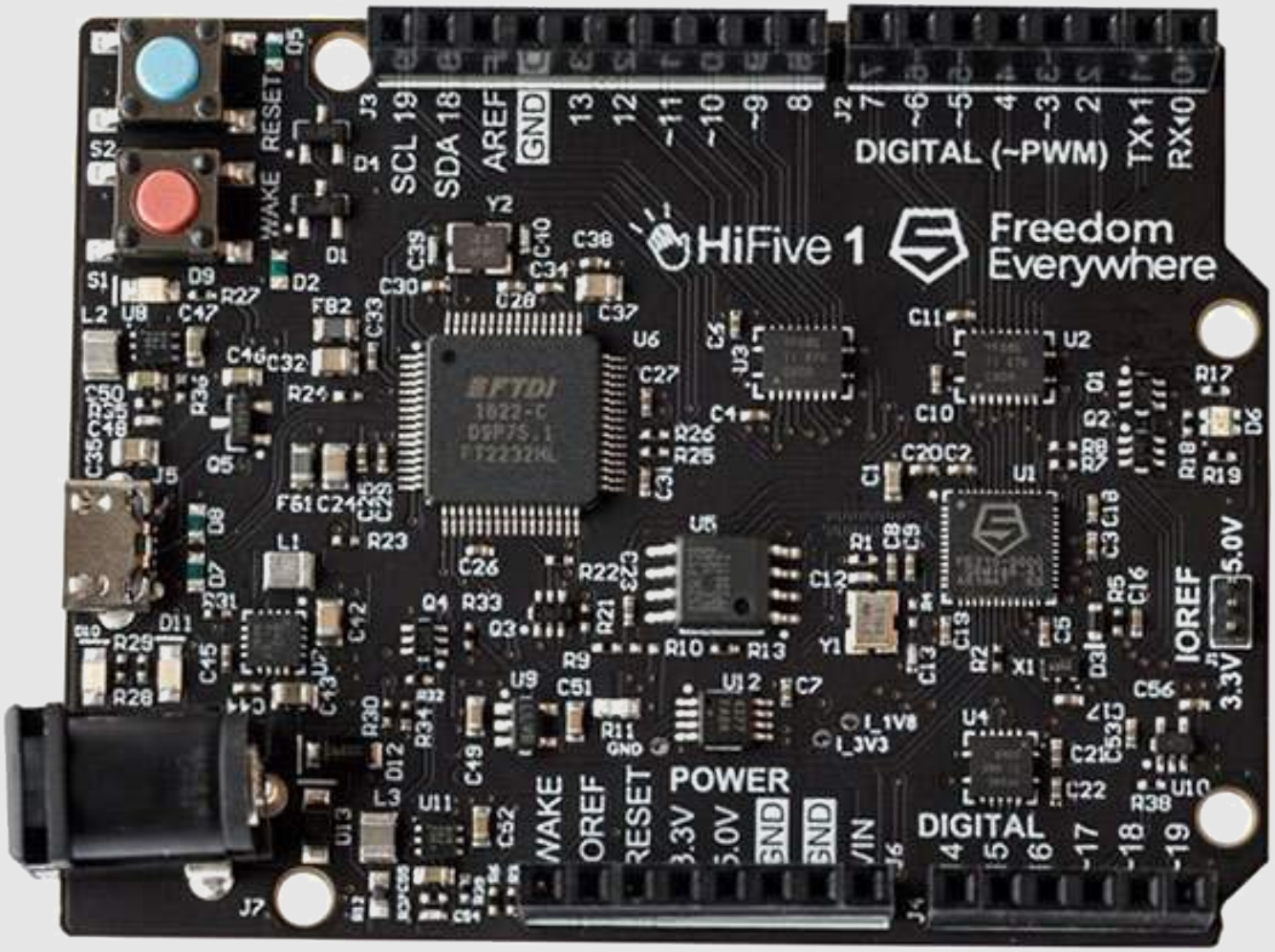
OpenMV 2 (ARM Cortex-M4F)

Crazyflie 2.0 (ARM Cortex-M4F)

BBC Micro:Bit (ARM Cortex-M0)



HiFive1 (RISC-V)



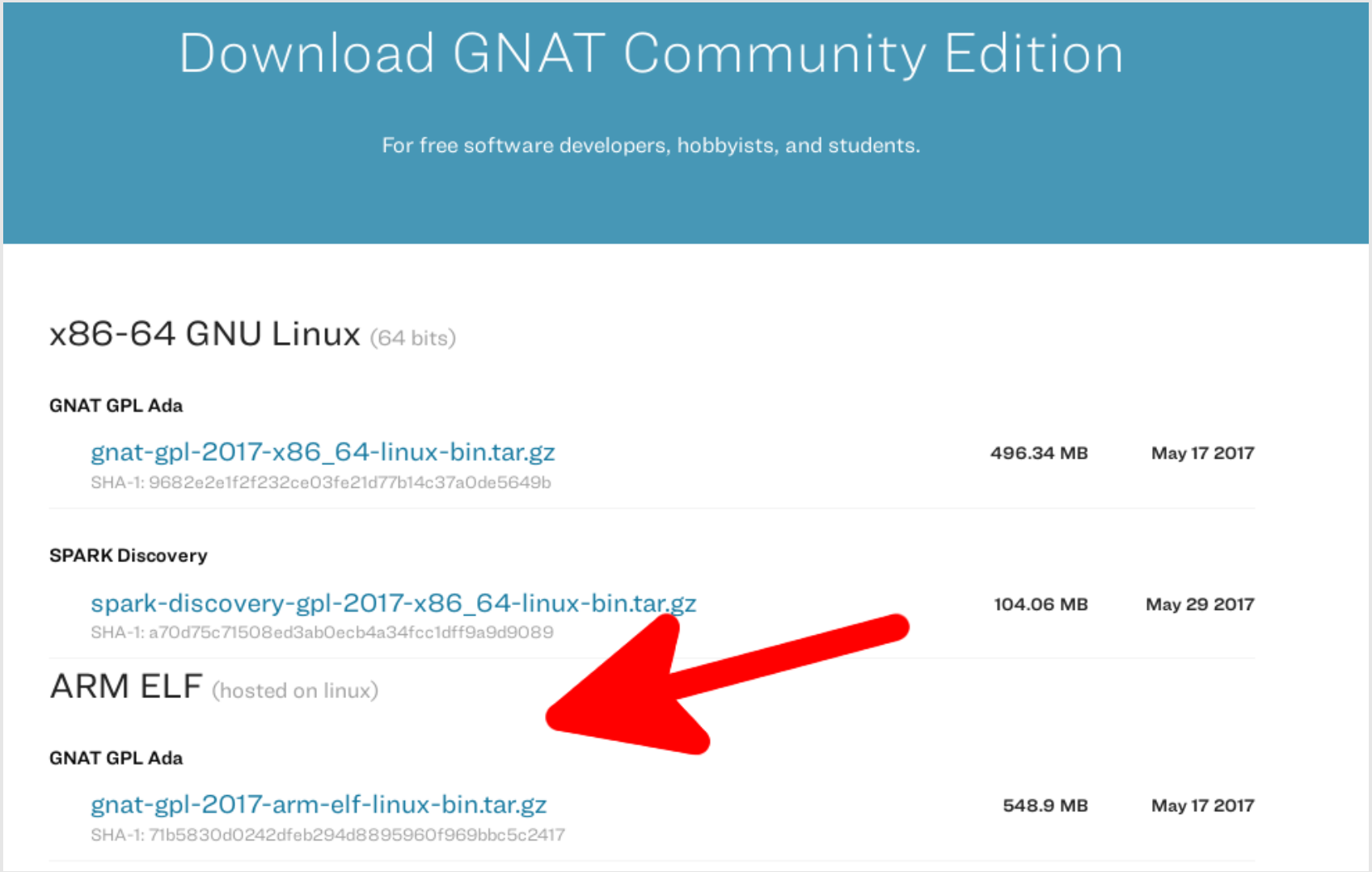
What's next?

TODOs:

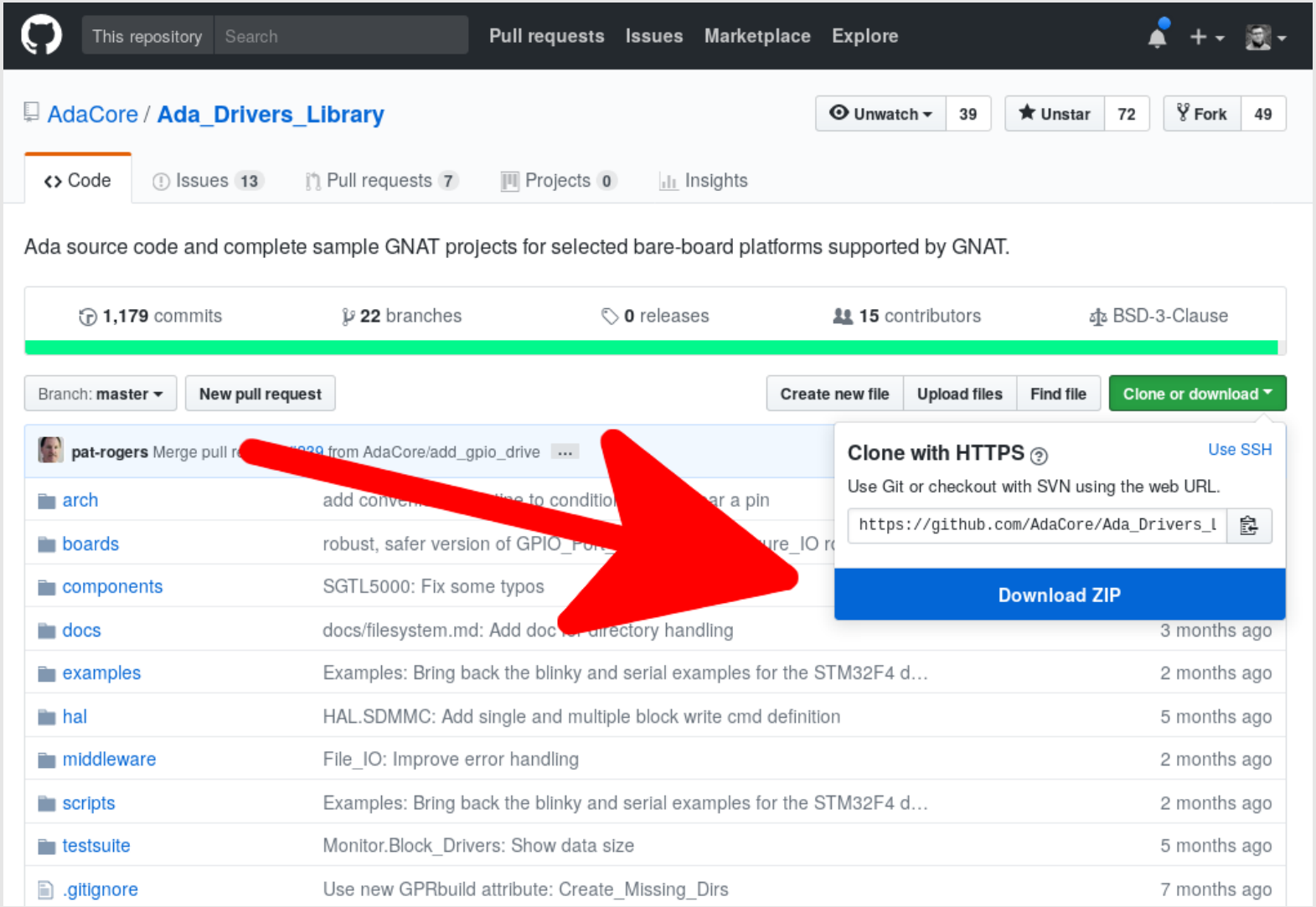
- New configuration and build system
- More documentation
- Basic out of the box support of all the Cortex-M devices
- Linux GPIO/I2C/SPI support (on the Raspberry Pi for instance)
- AVR platform
- More component drivers
- USB stack and drivers on the STM32
- Bluetooth Low Energy stack on the Micro:Bit

Getting started demo

Download and install the tools: adacore.com/community



Download Ada Drivers Library



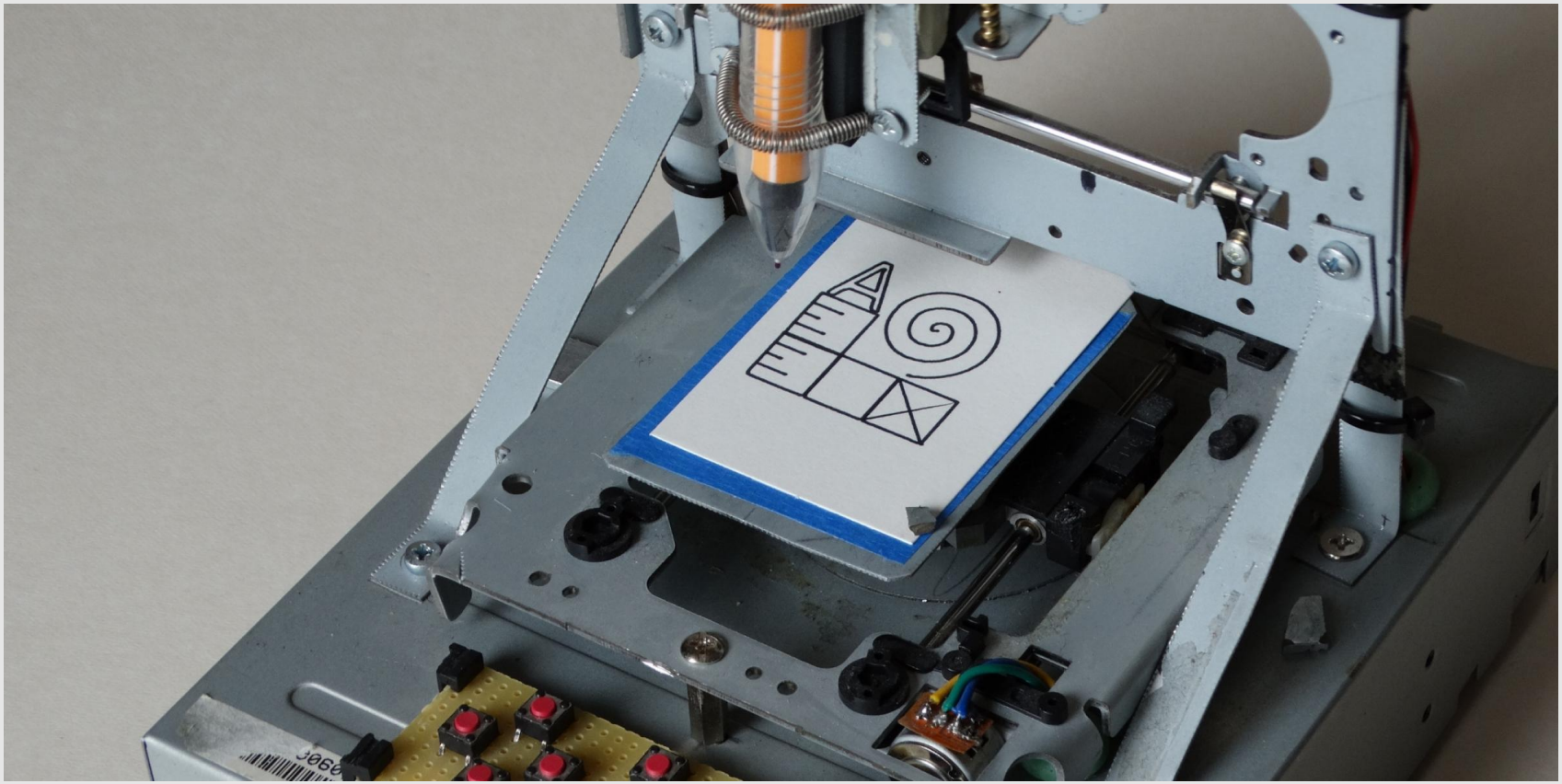
Some projects using the Ada Drivers Library

Crazyflie 2.0 Flight controller

blog.adacore.com/how-to-prevent-drone-crashes-using-spark

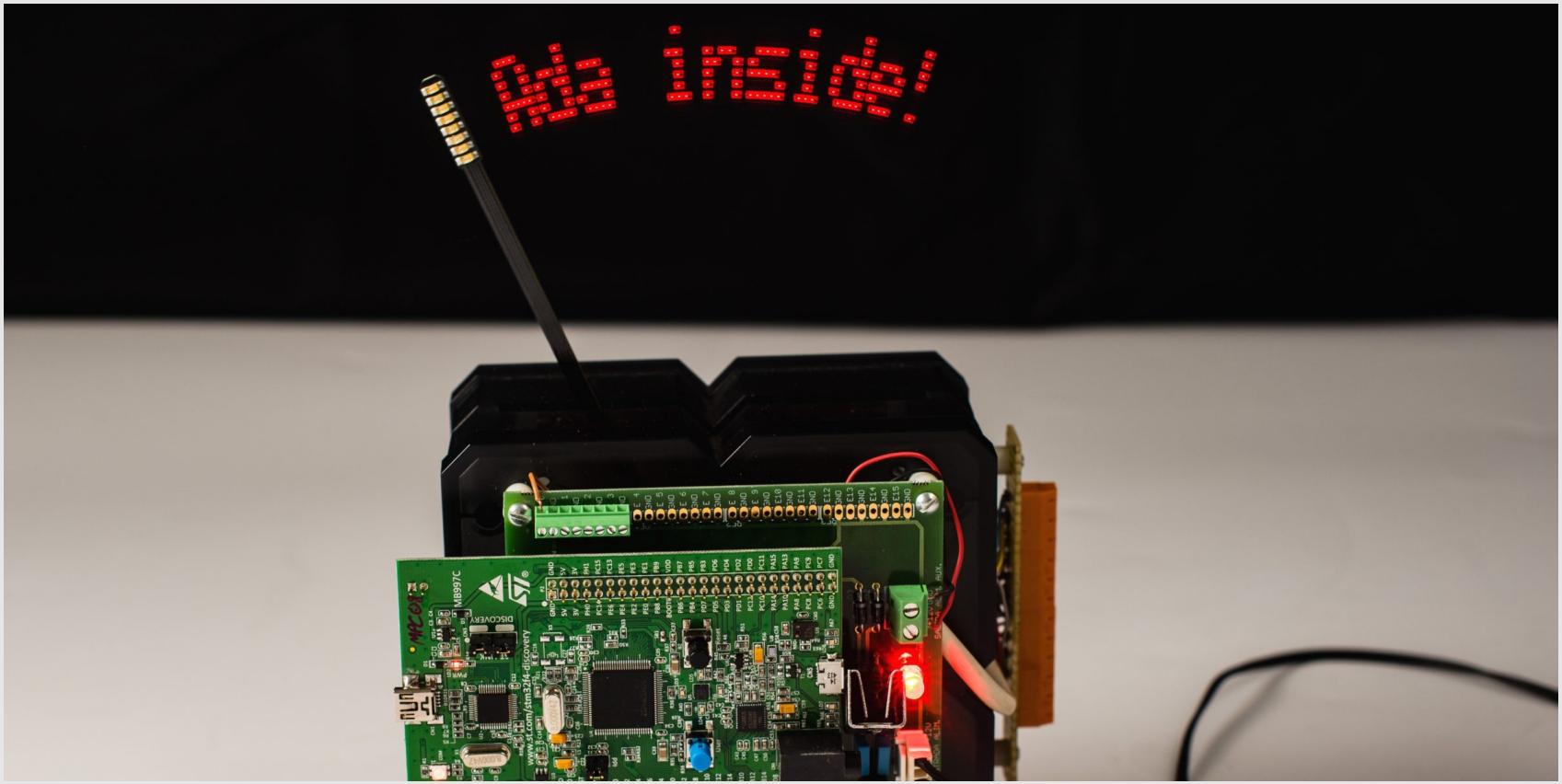
CNC Controller

blog.adacore.com/make-with-ada-arm-cortex-m-cnc-controller



Pendulum clock LED

blog.adacore.com/writing-on-air



DIY instant camera

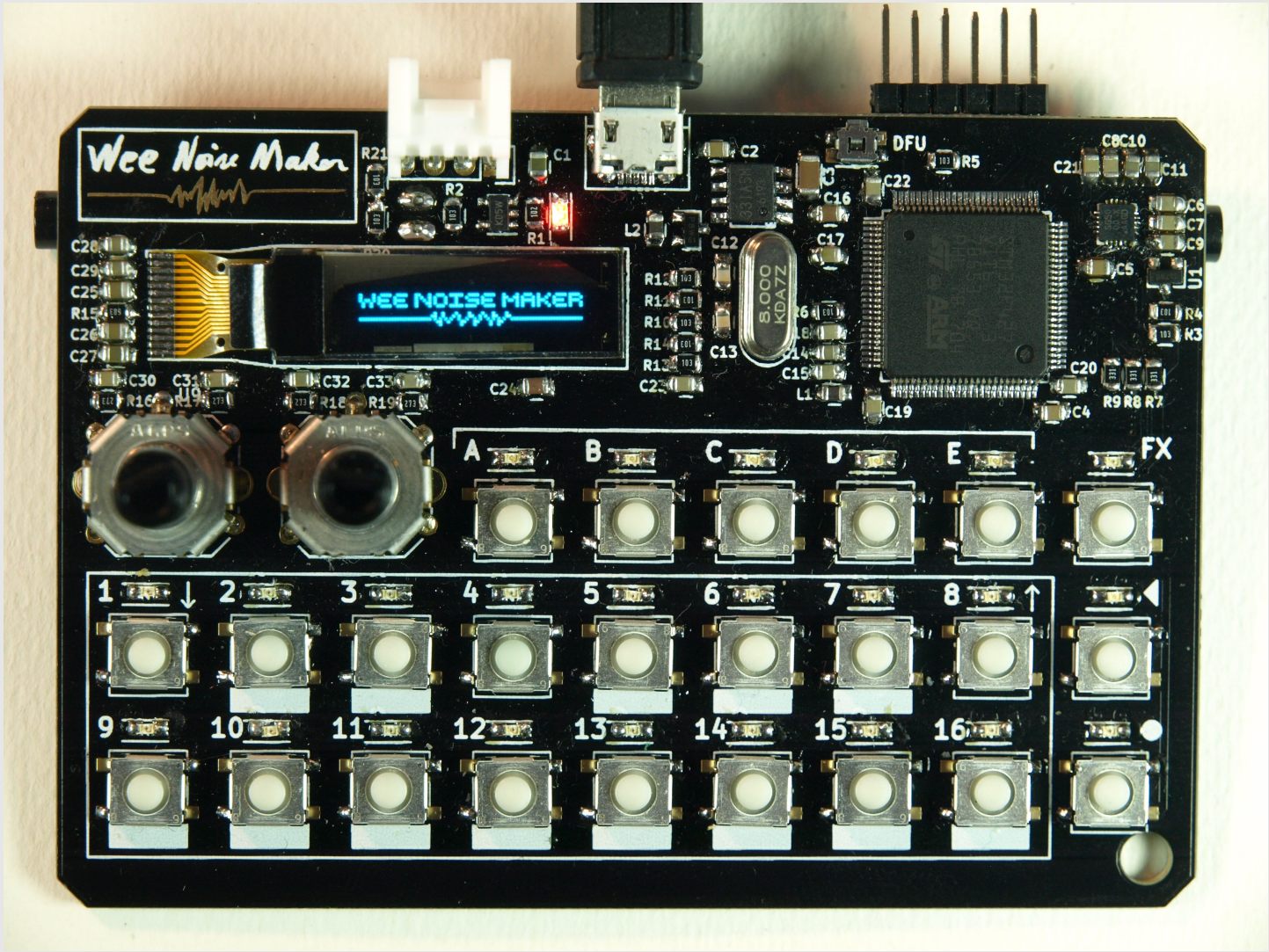
blog.adacore.com/make-with-ada-diy-instant-camera

Wolf

github.com/lambourg/Ada_Bare_Metal_Demos

Wee Noise Maker

github.com/Fabien-Chouteau/Wee-Noise-Maker

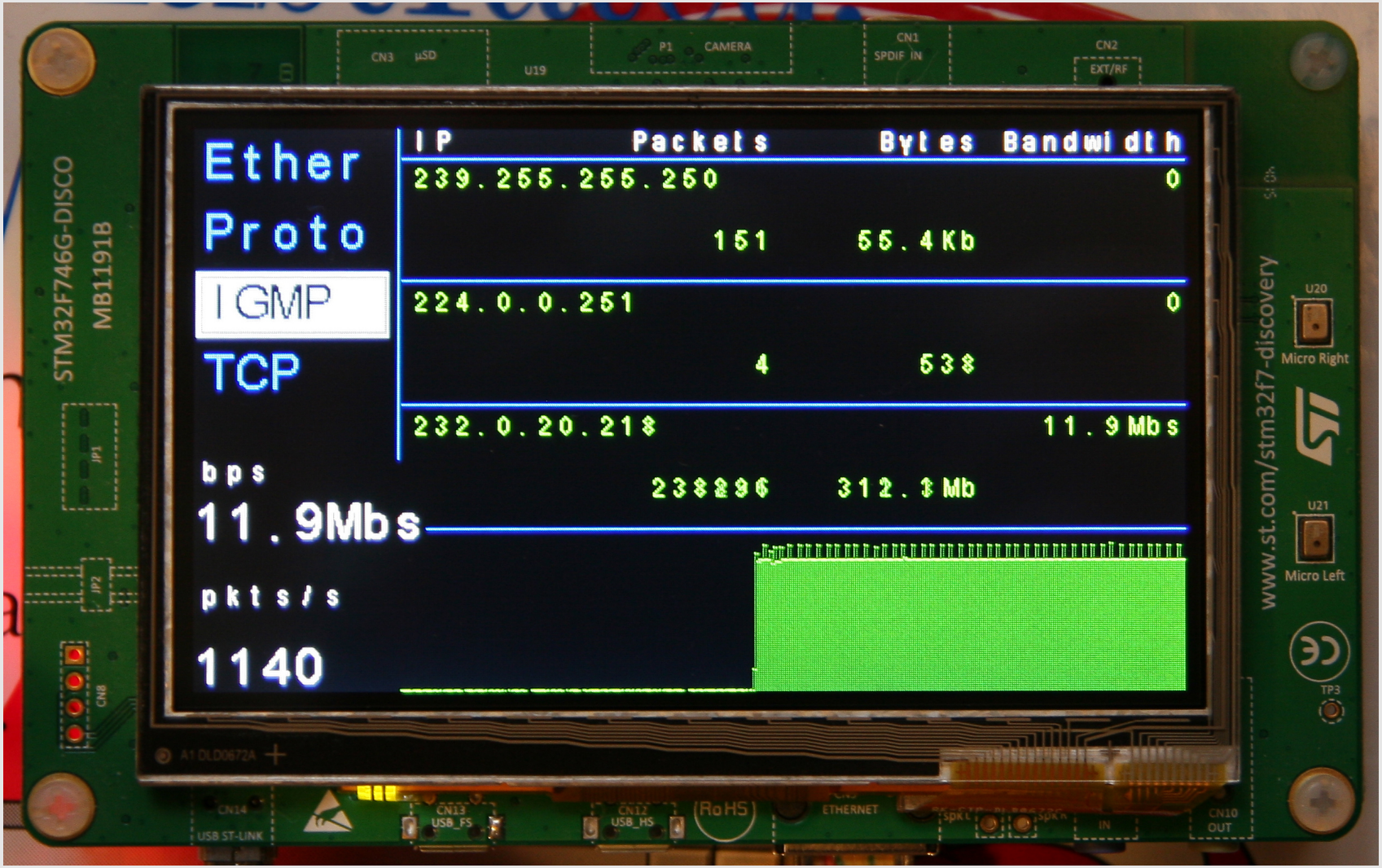


The Make with Ada Competition

- Embedded software project competition
- Open to everyone
- ~8000 euros in prize
- Stay tuned for the next edition (Twitter @adaprogrammers)

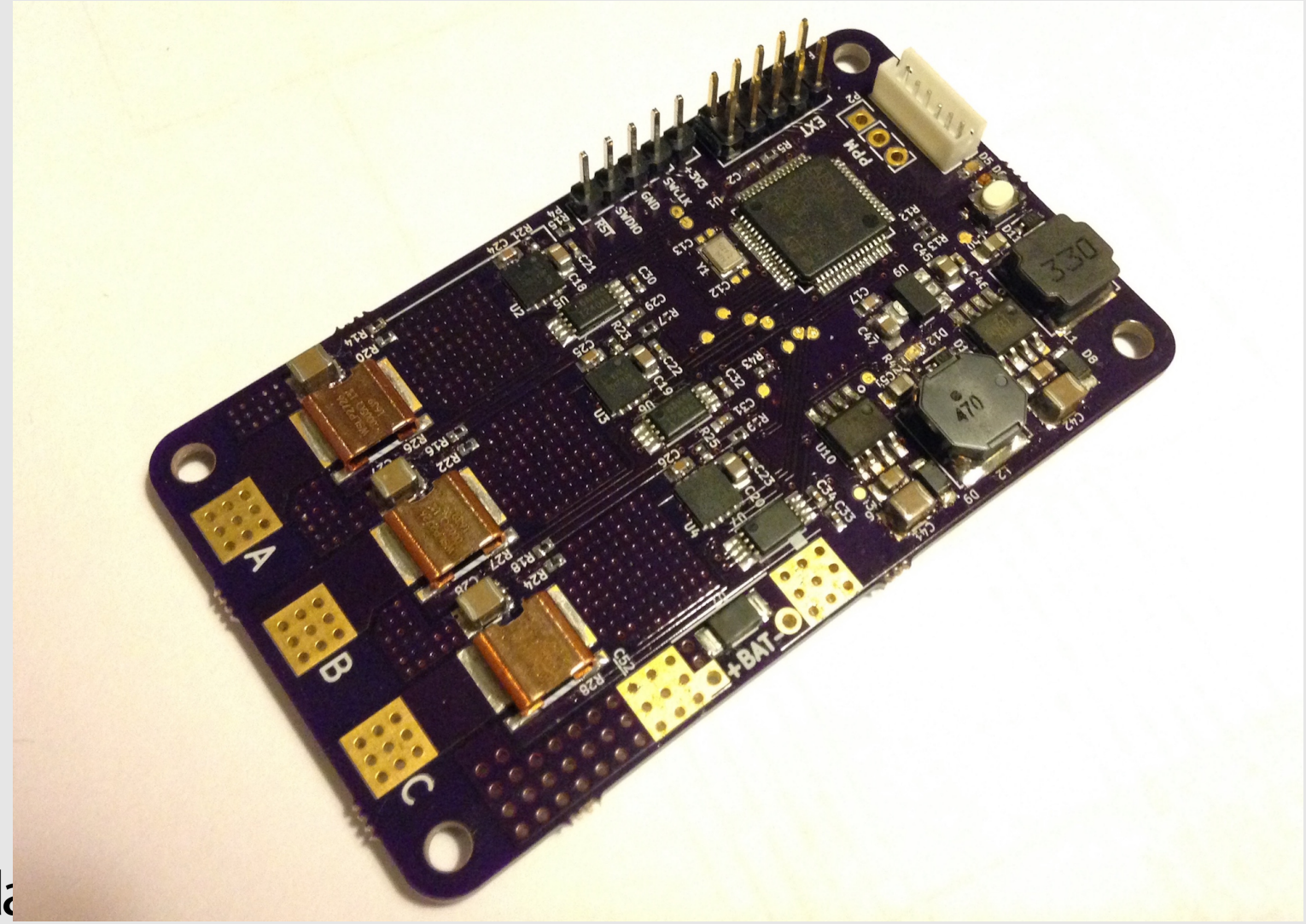
2016 Winner project (Stephane Carrez)

github.com/stcarrez/etherscope



2017 Winner project (Jonas Attertun)

blog.adacore.com/make-with-ada-2017-brushless-dc-motor-controller



What are you going to make?

- GitHub: github.com/AdaCore/Ada_Drivers_Library
- Twitter: @AdaProgrammers