Alternative languages for safe and secure RISC-V programming

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What do I mean by “alternative”?

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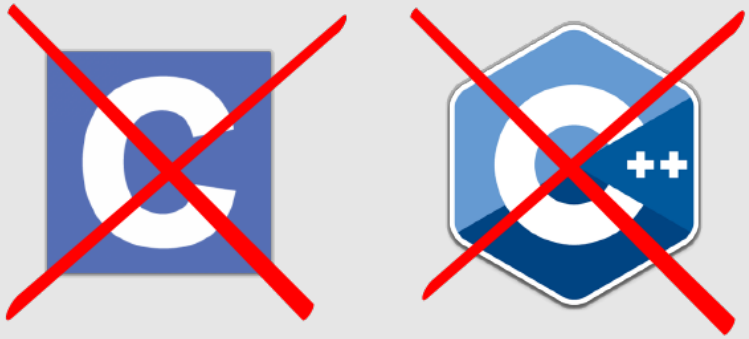
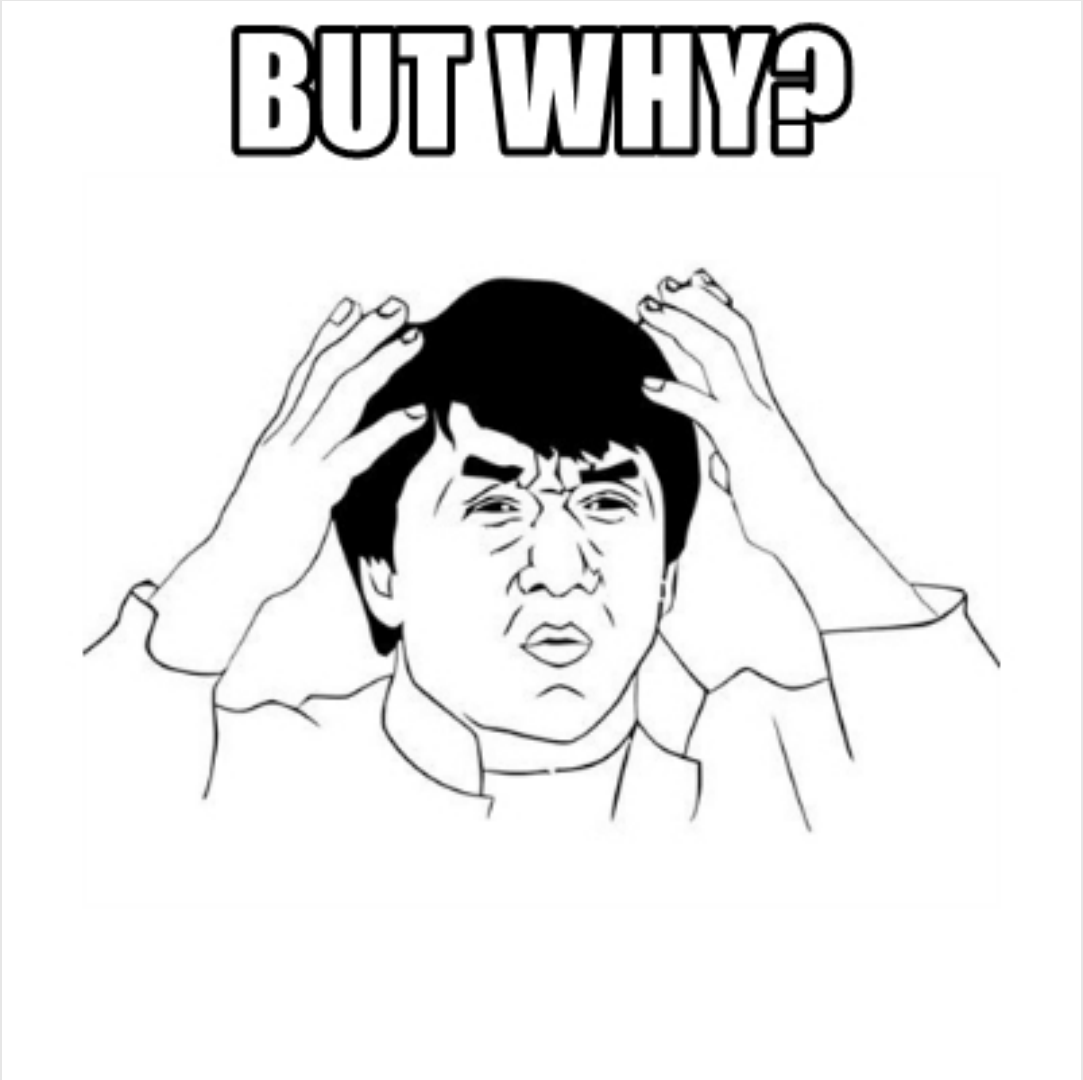
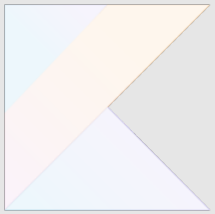



BUT WHY?

Ada 2012

SPARK

JS



Ada
2012


SPARK

JS

Ada and SPARK

- Designed for Safety and Security
- Powerful means of specification
- Strong type checking
- Object Oriented Programming
- Concurrent programming features
- Generic templates
- Encapsulation
- Hierarchical program composition / programming-in-the-large

Programming is all about communication

With:

- The compiler
- The other tools (static analyzers, provers, etc.)
- Users of your API
- Your team
- Yourself in a couple weeks. . .

Example

Specifications

```
type Servo_Angle is new Float range -90.0 .. 90.0
--  Servo rotation angle in degree

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

Contracts

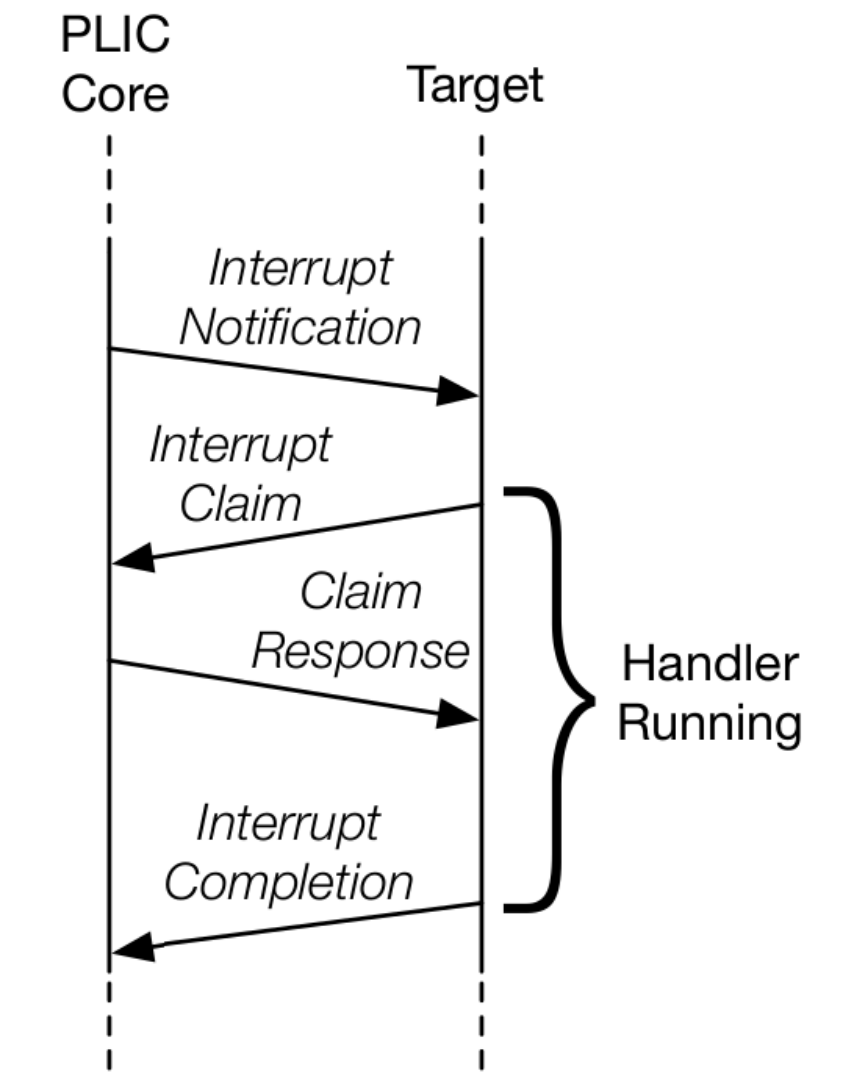
```
type Stack is tagged private;

function Empty (S : Stack) return Boolean;
function Full (S : Stack) return Boolean;

procedure Push (S : in out Stack; Val : Integer)
  with  Pre => not S.Full,
        Post => not S.Empty;

procedure Pop (S : in out Stack; Val : out Integer)
  with  Pre => not S.Empty,
        Post => not S.Full;
```

Example: Writing an API for the RISC-V PLIC



Example: Writing an API for the RISC-V PLIC

```
Max_Interrupt : constant := 15;

type Any_Interrupt_ID is
  range 0 .. Max_Interrupt + 1;

No_Interrupt : constant Any_Interrupt_ID := Any_Interrupt_ID'Last;
--  Special value indicating no interrupt

subtype Interrupt_ID is
  Any_Interrupt_ID range 0 .. Max_Interrupt;
```

Example: Writing an API for the RISC-V PLIC

```
function Claimed return Any_Interrupt_ID

  with Ghost;

--  Return the last claimed interrupt
```

Example: Writing an API for the RISC-V PLIC

```
function Claim return Any_Interrupt_ID

  with  Pre => Claimed = No_Interrupt,

        Post => Claimed = Claim'Result;

--  Claim an interrupt on the PLIC for the current hart and
--  return its ID. Return No_Interrupt if there was no pending
--  interrupts for the hart when the claim was serviced.
```

Example: Writing an API for the RISC-V PLIC

```
procedure Complete (Interrupt : Interrupt_ID)

   with Pre  => Claimed /= No_Interrupt
                 and then
                Interrupt = Claimed,

        Post => Claimed = No_Interrupt;

--  Signal an interrupt completion for the current hart
```

Checks

- At run-time
  - Checks inserted in the code
  - For debug or testing
- At Compile time
  - Compiler
  - Static analyzer
  - Formal verification (SPARK)

Functional Safety

Hardware mapping

```
--  High level view of the type
type Servo_Angle is new Float range -90.0 .. 90.0

--  Hardware representation of the type
  with Size      => 32,
       Alignment => 16;
```

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 with Size => 32;

--  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

```
#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

```
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

Interfacing with C / Assembly

```
with Interfaces.C; use Interfaces.C;

[...]

function My_C_Function (A : int) return int
  with Pre => A /= 0;

pragma Import (C, My_C_Function, "my_c_function");


function My_Ada_Function (A : int) return int;

pragma Export (C, My_Ada_Function, "my_ada_function");
```

Where Ada/SPARK is used?

Emerging domains

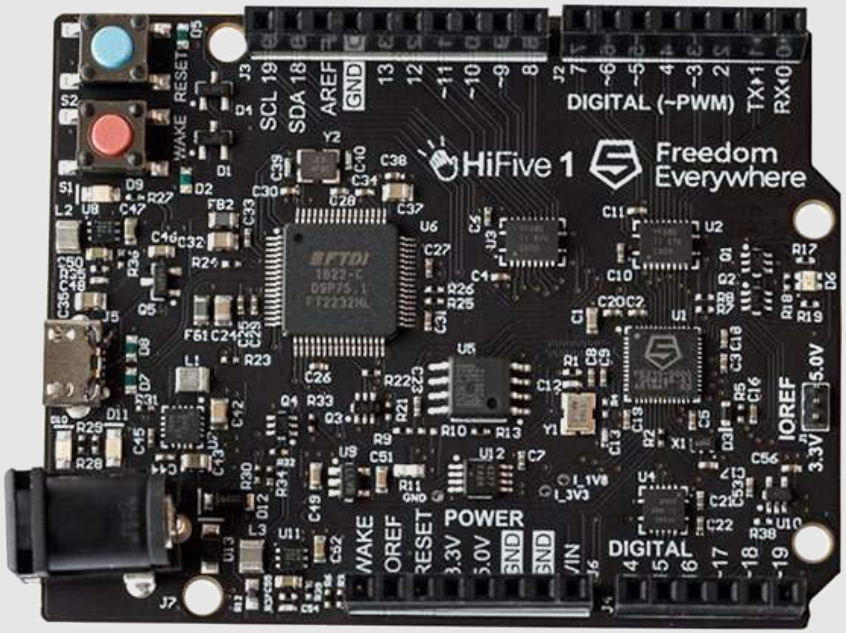
- Software development eco-system:
  - GNAT: Ada compiler part of GCC
  - IDEs
  - Code Coverage
  - Static analysis
  - Formal verification
  - Simulink code generator
- Open-source
- Ada, SPARK, C, C++
- Dozens of platforms (including RISC-V :)
- Front line support
- DO-178, EN 50128, ISO 26262

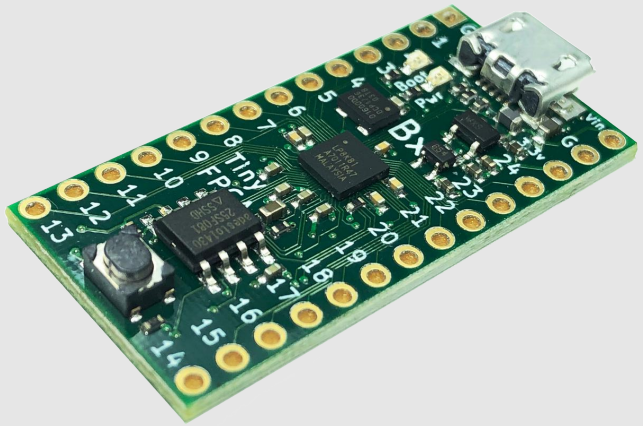
AdaCore joins the RISC-V foundation

AdaCore

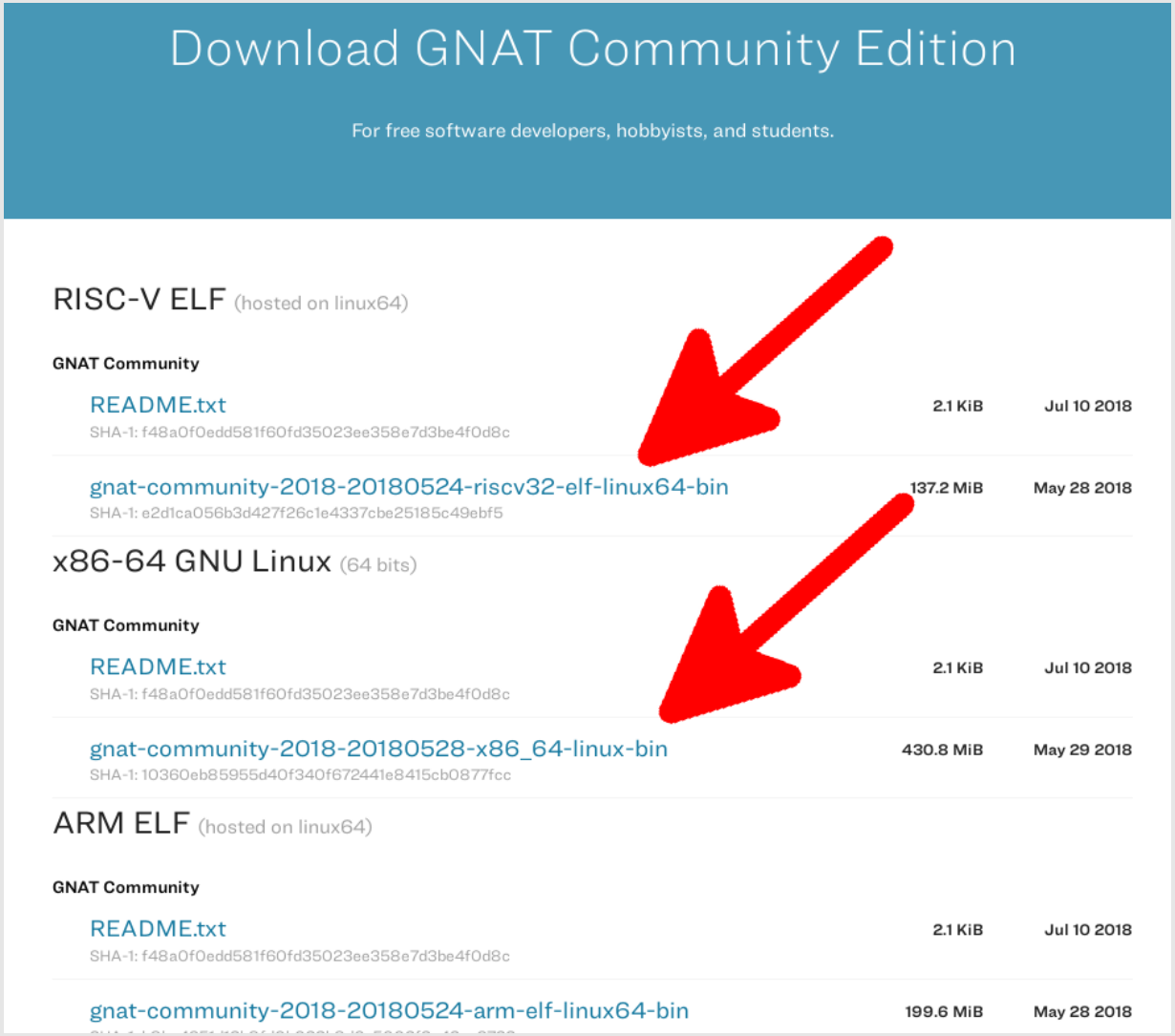
Getting started

Hardware

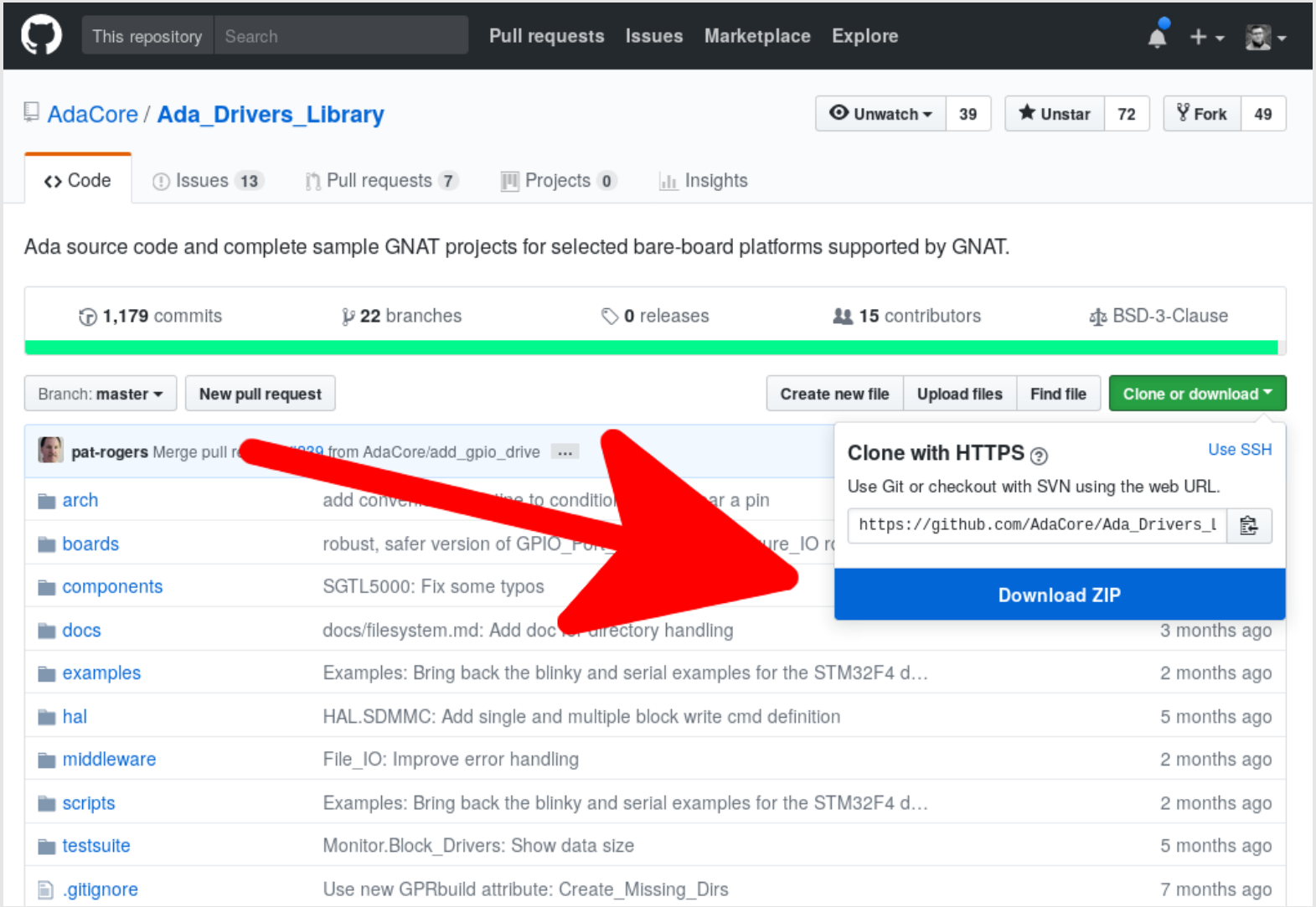

HiFive 1
Freedom
Everywhere
DIGITAL (~PWM)
POWER
DIGITAL
IOREF
3.3V
5.0V



Download and install the tools: adacore.com/community



Download Ada Drivers Library



Keep the door open

What as already been done

- Open specs and documentation
- RISC-V support in open-source tools:
  - Compilers (GCC, LLVM)
  - Debuggers (Gdb, openocd)
  - Simulators (QEMU)

Challenges

- Complexity of extension combinations
  RV(32|64|128) I M A C B [F|D|Q] ...
- Deviation from the standard
- Custom/proprietary extensions
- Reference implementations in C

Hardware description

Do we need to go beyond SVD?

- Registers ✓
- Interrupts ✓
- CPU specs ?
- RAM and ROM banks ?
- Modular representation ?
- Tools that generate SVD from custom design ?

Resources

- learn.adacore.com : interactive learning website
- Twitter : @AdaProgrammers
- Reddit : r/ada