Embedded Ada/SPARK Programming in 2022

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Scope: MCUs

- Micro-controllers
  - “Simple” devices
  - A few KiB sometimes MiB of RAM and ROM
  - No virtual memory
  - A lot of inputs/outputs
- No Operating System (bare-metal)

Ada/SPARK for embedded: Pros

- Benefits of high-level language
    - Contracts
    - Tagged types
    - Discriminated types
    - Arrays
    - Etc.
- Representation Clauses
- Interfacing with C
- Less debugging (debugging is hard in embedded)
- SPARK: formal proof
- Alire!
- Ravenscar Tasking

Ravenscar Tasking

A.K.A There's a mini-RTOS in my language[1]

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

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

Ada/SPARK for embedded: Cons

- Ravenscar Tasking
- Secondary Stack
- Toolchain availability
- Drivers/BSP availability
- Library ecosystem

What do you need?

What do you need?

- Board Support Package (BSP)
  - Run-time
  - Startup code
  - Linker scripts
  - Drivers
- Libraries
- Toolchain

Ada/SPARK Integration in Embbedded Projects

Startup	Drivers	Functional	Libraries
Ada	Ada	Ada	Ada
C	C	Ada	C
C	Ada/C	Ada	C/Ada
...	...	Ada	...

Board Support Package

ARM Microcontroller Market

- Dozens of vendors (ST, Microchip, NXP, Nordic, Cypress, Infineon, nuvoTon, TI, Raspberry Pi, etc.)
- 8 variants (Cortex-M0/M0+/M1/M3/M4/M7/M23/M33)
- Thousands of individual parts (4000+):
  - STM32F446RET6
  - nRF51822-QFAA-R
  - APM32F103C6
  - ATSAME54N20A
  - HT32F22366
  - XMC1302-Q040x0032
  - EFM32GG280F1024
  - MB9AF155M
  - S6E2CC8H0A
  - MK60DN256xxx10
  - LM4F122H5QD
  - LPC1114FHN33/202
  - TMPM3H2FWDUG

How can we support so many devices?

Startup and run-time

The “generic” ZFP run-times

Zero-FootPrint run-times without parts that are specific to a given MCU or board

That means without:

- Linker script
- Startup code (crt0.S)

startup-gen

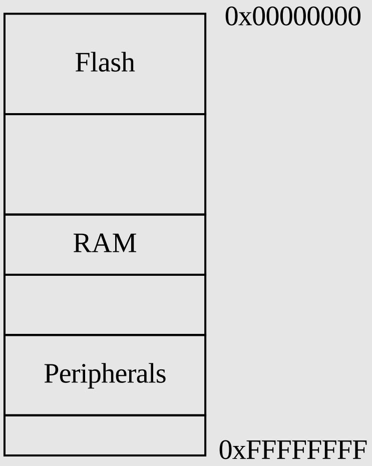
```
package Device_Configuration is
    for Cpu_Name use "ARM Cortex-M4F";
    for Memories use ("HSRAM", "FLASH");
    for Boot_Memory use "FLASH";

    for Mem_Kind ("FLASH") use "rom";
    for Address ("FLASH") use "0x08000000";
    for Size ("FLASH") use "0x80000";

    for Mem_Kind ("HSRAM") use "ram";
    for Address ("HSRAM") use "0x20000000";
    for Size ("HSRAM") use "0x30000";
end Device_Configuration;
```

startup-gen

```
$ alr get/with startup_gen
$ startup-gen -P samd51.gpr -l src/link.ld -s src/crt0.S
```

Peripheral Drivers

Memory Mapped Registers



Memory Mapped Registers

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

```c
#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

```ada
--  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

```ada
--  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;
```

Let’s focus on one microcontroller

- STM32F446RET6
- 46 peripherals
- 881 memory mapped registers
- 6820 fields in the registers

Who wants to write all the representation clauses for that beast?

System View Description (SVD)

```
<field>
  <name>SENSE</name>
  <description>Pin sensing mechanism.</description>
  <lsb>4</lsb> <msb>5</msb>
  <enumeratedValues>
    <enumeratedValue>
      <name>Disabled</name>
      <description>Disabled.</description>
      <value>0x00</value>
    </enumeratedValue>
 [...]
```

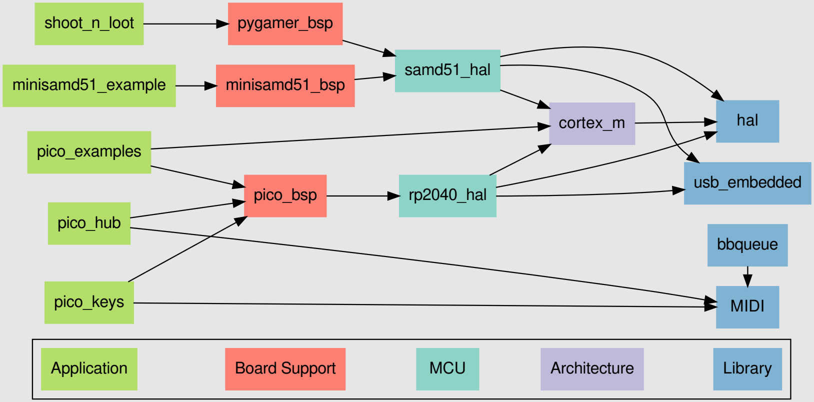
SVD2Ada

Generates Ada representation clauses from SVD file.

```
$ alr get/with svd2ada
```

Libraries

Embedded projects with Alire



Available Toolchains

ARM

RISC-V

AVR®

What about SPARK?

What about SPARK?

- All of the above apply
- Easier to do SPARK in embedded
- Easier to start with libraries

Questions ?

Thank you !