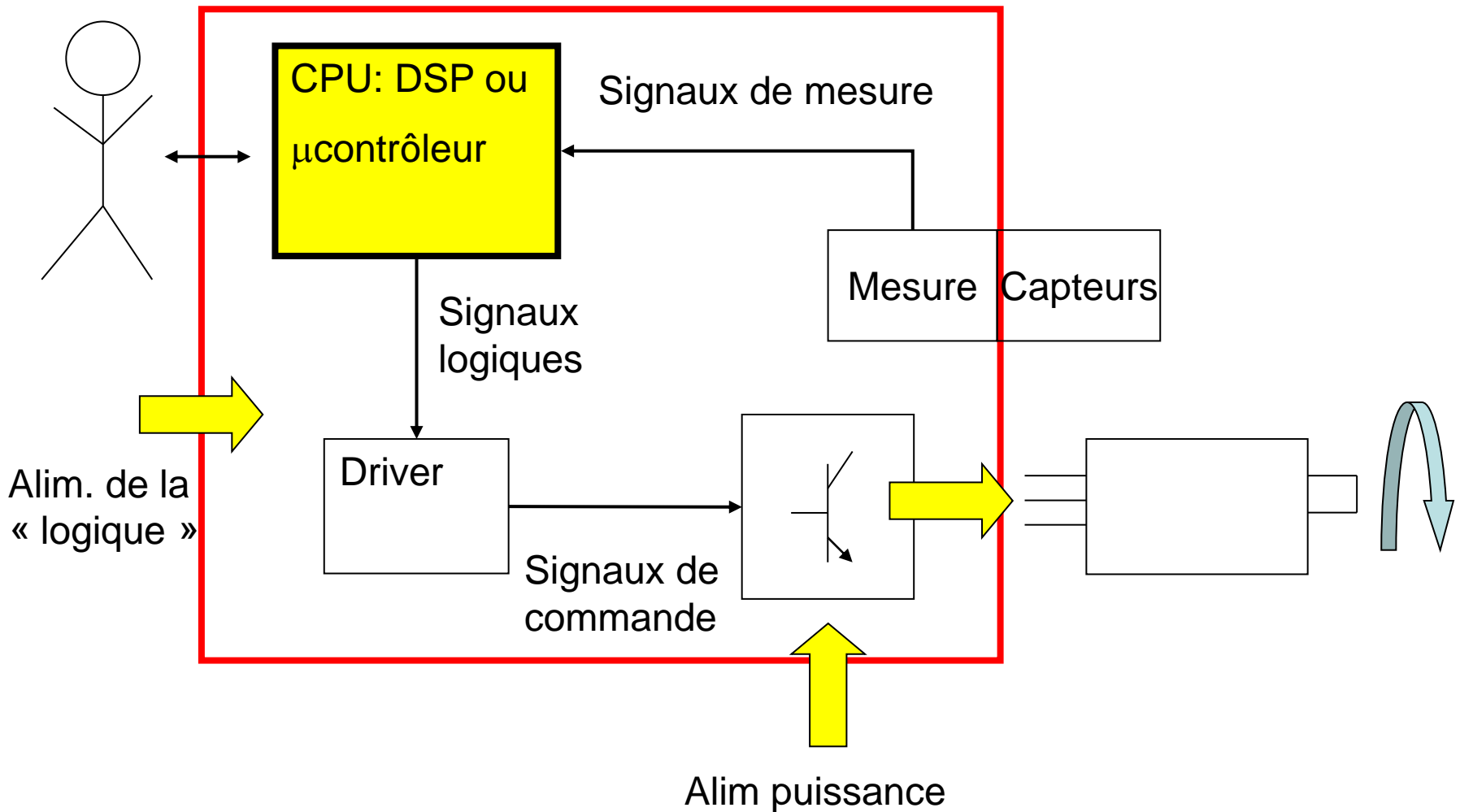


# Commande embarquée de moteurs

## 1 Prise en main du Microcontrôleur Microcontrôleur

*Christian Koechli*

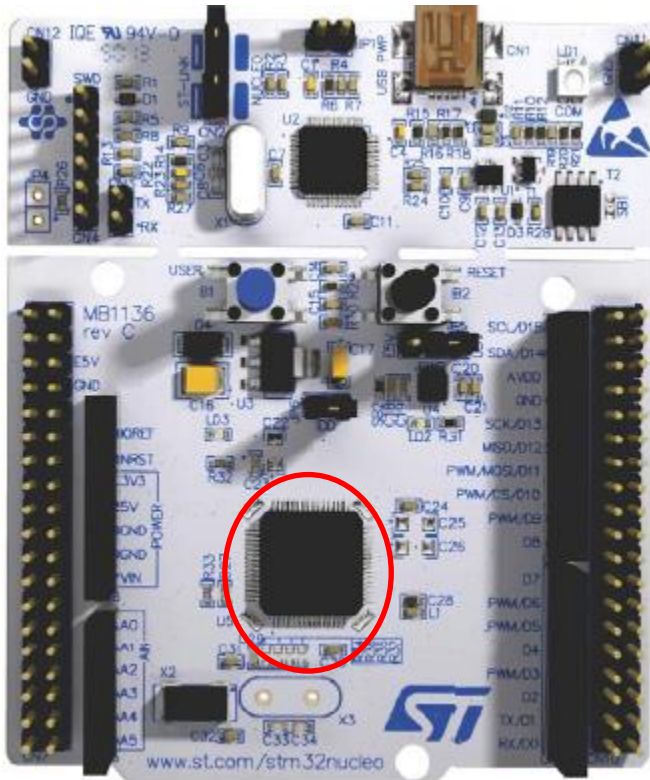
# Composants de l'électronique de commande



# Tâches du CPU

- Calculer les paramètres de commutation et de réglage
- Effectuer la commande des transistors (Pwm)
- Mesurer les grandeurs de réglage (AD, IO)
- Communiquer avec l'utilisateur (CAN, RS232, SPI, I2C, AD, IO)
- Surveiller que rien ne casse

# μC: STM32F401RE



- ARM Cortex M4 (32bit) avec FPU + DSP
- 512KB flash /96KB RAM
- 84Mhz
- 64 pattes
- Basse consommation
- 4.5\$ (1000 pièces)



# Famille STM32









## STM32 32-bit Arm® Cortex®-M MCUs

Category	MCU Model	CoreMark	Frequency	Cortex Core	Special Features
High Performance	STM32H7	3224	480 MHz	Cortex-M7	Optimized for Mixed-signals applications
	STM32F2	398	120 MHz	Cortex-M3	
	STM32F4	608	180 MHz	Cortex-M4	
Mainstream	STM32G0	142	64 MHz	Cortex-M0+	Optimized for Mixed-signals applications
	STM32F0	106	48 MHz	Cortex-M0	
	STM32F1	177	72 MHz	Cortex-M3	
	STM32F3	245	72 MHz	Cortex-M4	Optimized for Mixed-signals applications
Ultra-low-power	STM32L0	75	32 MHz	Cortex-M0+	
	STM32L1	93	32 MHz	Cortex-M3	
	STM32L5	442	110 MHz	Cortex-M33	
	STM32L4+	409	120 MHz	Cortex-M4	Optimized for Mixed-signals applications
	STM32L4	273	80 MHz	Cortex-M4	
Wireless	STM32WB	216	32 MHz / 64 MHz	Cortex-M0+ / Cortex-M4	Optimized for Mixed-signals applications, Cortex-M0+ Radio Co-processor
	STM32WL	161	48 MHz	Cortex-M4	

Legend: ● Optimized for Mixed-signals applications ● Cortex-M0+ Radio Co-processor

## STM32 Solutions

-  Artificial Neural Networks
-  Graphic User Interface
-  STM32 Motor Control
-  STM32 Connectivity
-  STM32Cube Ecosystem
-  STM32 Community
-  STM32 Education

- ART Accelerator™ enabling 0 wait state executing from internal Flash
- Up to 2x USB2.0 OTG FS/HS (except for access lines)
- SDIO
- USART, SPI, I<sup>2</sup>C
- I<sup>2</sup>S + audio PLL
- 16 and 32-bit timers
- Up to 3x 12-bit ADC (0.41 μs)
- Up to 2x 12-bit DAC
- External memory controller
- Low voltage 1.71 to 3.6 V

STM32 F4	FCPU (MHz)	Flash (bytes)	RAM (KB)	Ethernet I/F IEEE 1588		Camera I/F	SDRAM I/F		SAI3 I/F	Chrom-ART Graphic Accelerator™	TFT LCD controller	MPI DSI		
				2x CAN			Dual Quad-SPI	SPDIF RX						
<b>Advanced lines</b>														
STM32F469 <sup>2</sup>	180	512 K to 2 M	384	•	•	•	•	•	•	•	•	•		
STM32F429 <sup>2</sup>	180	512 K to 2 M	256	•	•	•	•	•	•	•	•	•		
STM32F427 <sup>2</sup>	180	1 to 2 M	256	•	•	•	•	•	•	•	•	•		
<b>Foundation lines</b>														
STM32F446	180	256 K to 512 K	128	•	•	•	•	•	•	•	•	•		
STM32F407 <sup>2</sup>	168	512 K to 1 M	192	•	•	•	•	•	•	•	•	•		
STM32F405 <sup>2</sup>	168	512 K to 1 M	192	•	•	•	•	•	•	•	•	•		
Product lines	FCPU (MHz)	Flash (Kbytes)	RAM (KB)	RUN current (μA/MHz)	STOP current (μA)	Small package (mm)	FSMC (NOR/PSRAM/LCD support)	QSPI	DFSDM	CAN 2.0B	DAC	TRNG	DMA Batch Acquisition Mode	USB 2.0 OTG FS
<b>Access lines</b>														
STM32F401	84	128 to 512	up to 96	Down to 128	Down to 10	Down to 3x3								•
STM32F410	100	64 to 128	32	Down to 89	Down to 6	Down to 2.553x 2.579					•	•	BAM	-
STM32F411	100	256 to 512	128	Down to 100	Down to 12	Down to 3.034x 3.22							BAM	•
STM32F412	100	512 to 1024	256	Down to 112	Down to 18	Down to 3.653x 3.651	•	•	•	•		•	BAM	• +LPM <sup>4</sup>
STM32F413 <sup>2</sup>	100	1024 to 1536	320	Down to 115	Down to 18	Down to 3.951x 4.039	•	•	•	•		•	BAM	• +LPM <sup>4</sup>

Notes:

1. 1.7 V min on specific packages
2. The same devices are also found with embedded HW AES encryption (128-/256-bit) named STM32F423
3. Serial Audio Interface
4. Link Power Management

Flash size / RAM size (bytes)

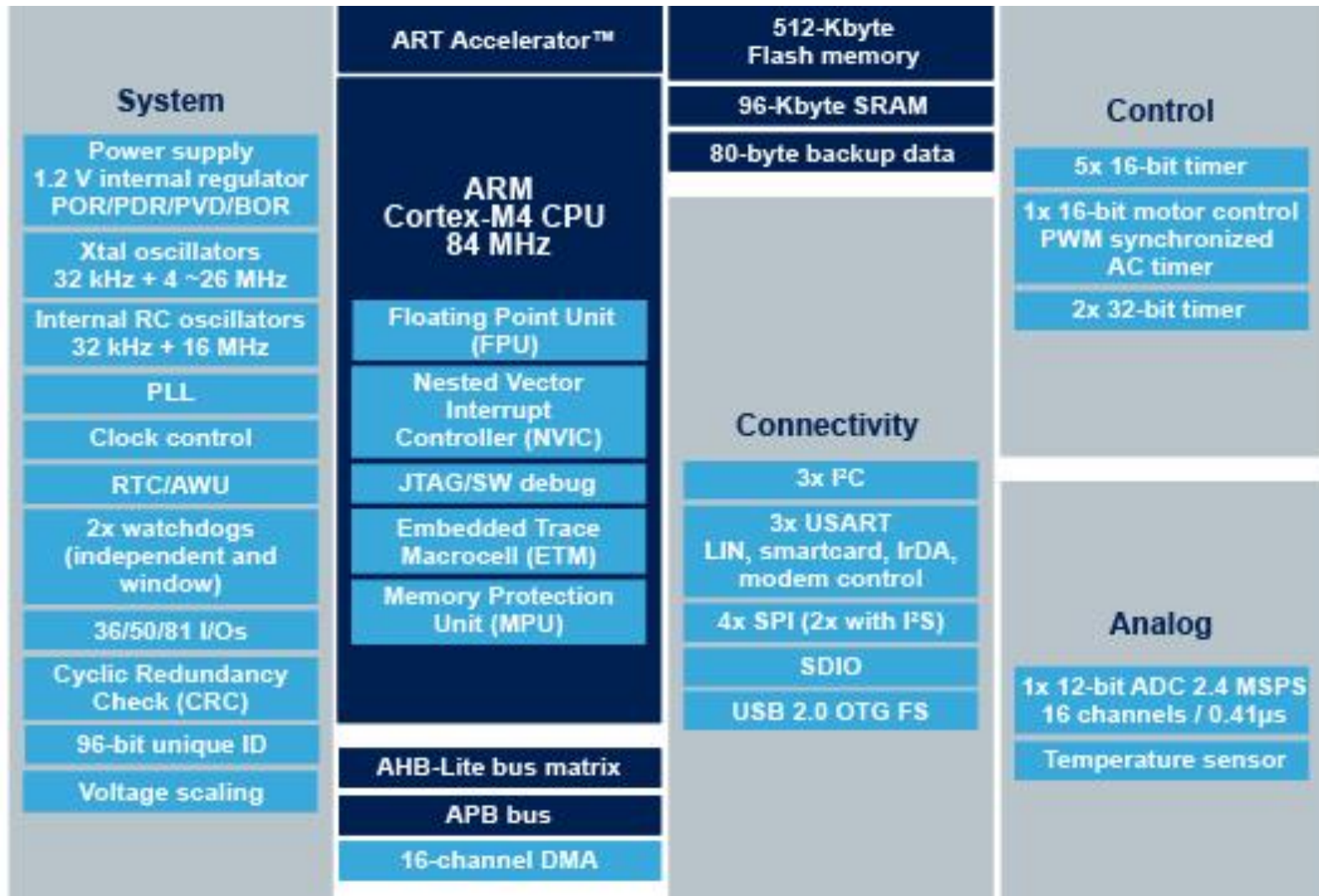


ARM® Cortex®-M4 (DSP + FPU) – Up to 180 MHz • ART Accelerator™ • SDIO • USART, SPI, I²C • I²S + audio PLL • 16 and 32-bit timers • 12-bit ADC (0.41 μs) • True Random Number Generator • Batch Acquisition Mode • Low voltage 1.7 to 3.6 V • Temperature: • -40 °C to 125 °C	Access lines	FCPU (MHz)	Flash (Kbytes)	RAM (KB)	RUN current (μA/MHz)	STOP current (μA)	Small package (mm)	FSMC (NOR/PSRAM/LCD support)	QSPI	DFSDM	CAN 2.0B	DAC	TRNG	DMA Batch Acquisition Mode	USB 2.0 OTG FS	
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	STM32F411	100	256 to 512	128	Down to 100	Down to 12	Down to 3.034x 3.22								BAM	•
	STM32F412	100	512 to 1024	256	Down to 112	Down to 18	Down to 3.653x 3.651	•	•	•	•			•	BAM	• +LPM¹
	STM32F413²	100	1024 to 1536	320	Down to 115	Down to 18	Down to 3.951x 4.039	•	•	•	•			•	BAM	• +LPM¹

Notes:

1. Link Power Management
2. The same devices are also found with embedded HW AES encryption (128-/256-bit) named STM32F423

# STM32F401RE



# Interruptions

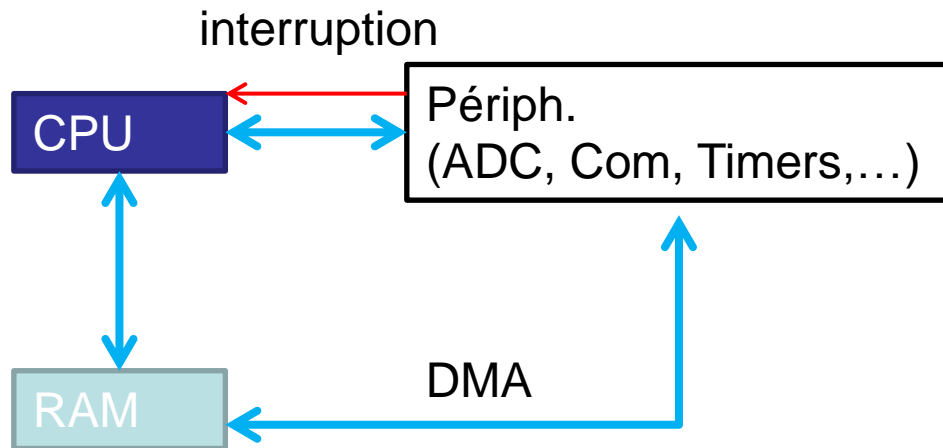
- 16 ARM Cortex M4
- 52 lignes d'interruption masquables (NVIC)
- 16 niveaux de priorité

# Interruption / événement

- Une interruption coupe l'exécution du programme
- La plupart des routines d'interruption peuvent/doivent être reprogrammées
- Un événement n'interrompt pas le programme
- Il permet de déclencher l'action d'un autre périph. sans intervention du «CPU»

# DMA

- Accès direct à la mémoire au lieu d'interrompre le CPU



# Conclusion

- Unité de calcul
- Périphériques
- Interruptions
- DMA