

PSI3441 – Arquitetura de Sistemas Embarcados

Conversor Analógico-Digital - ADC

Escola Politécnica da Universidade de São Paulo

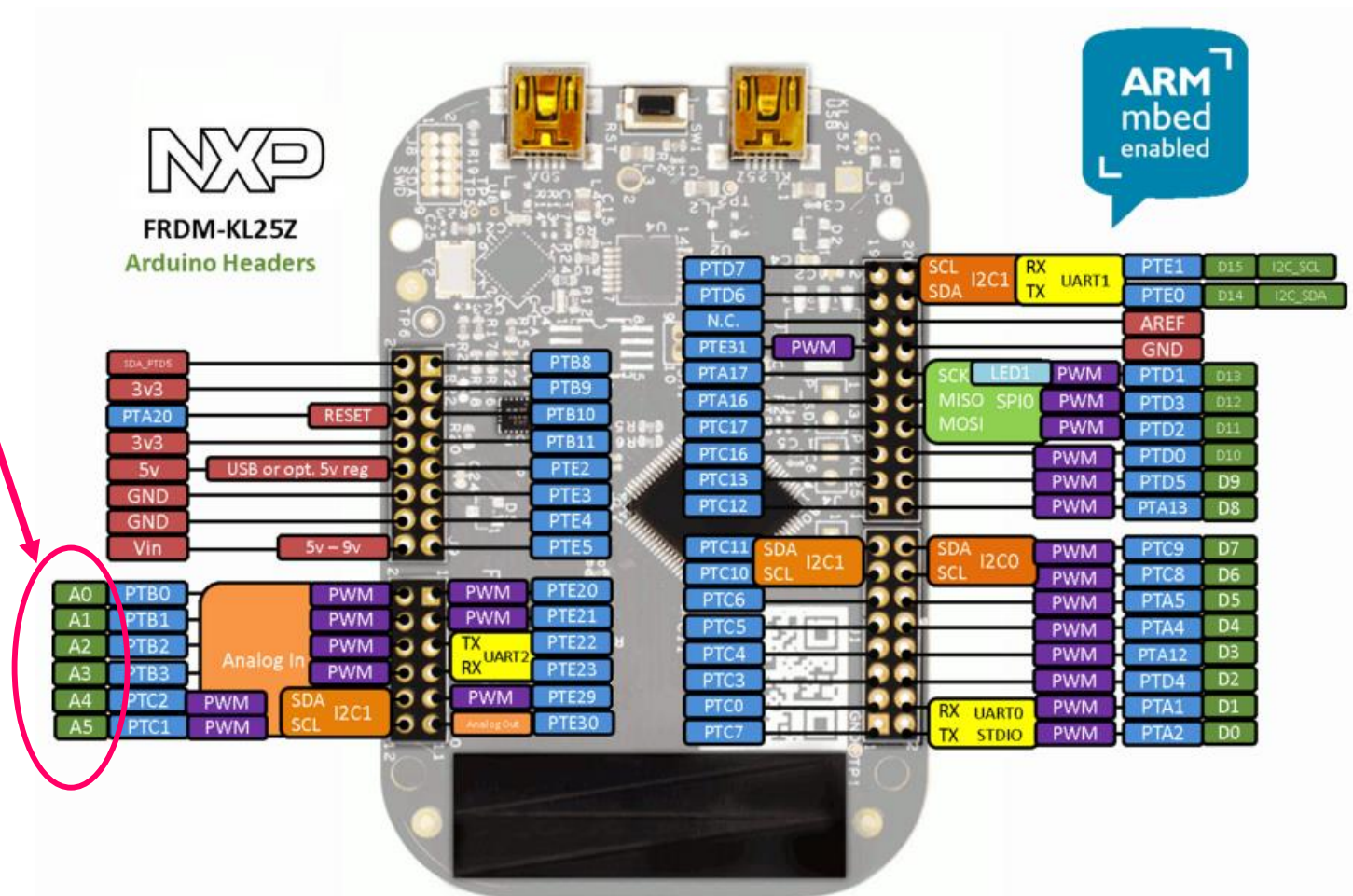
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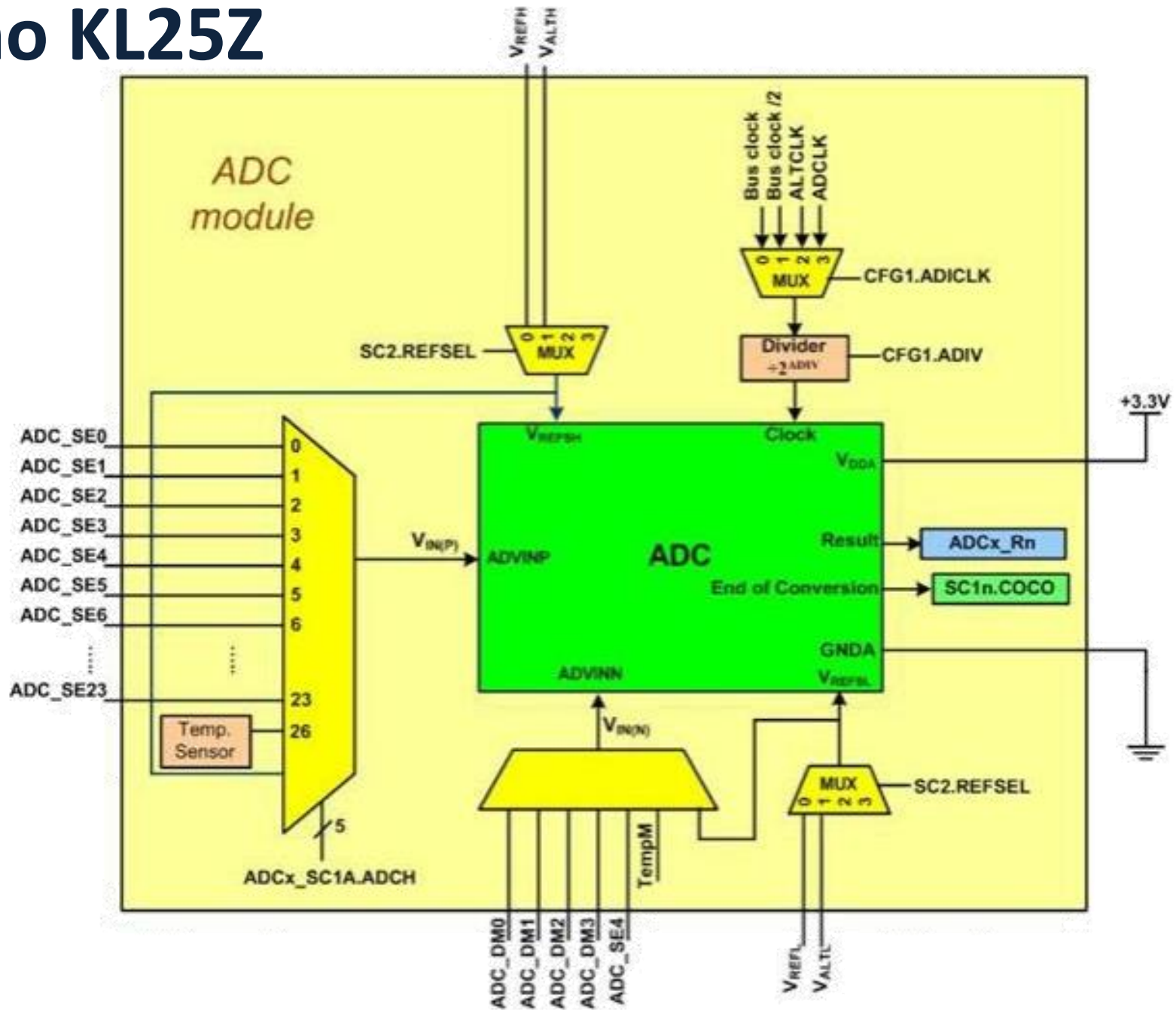
ADC no KL25Z

- ADC de aproximação sucessiva
- 16 bits
- 6 canais





ADC no KL25Z





Configuração no CodeWarrior com PE

1) Adicionar o componente ADC

The screenshot displays the CodeWarrior Development Studio interface. The main window is titled "C/C++ - CodeWarrior Development Studio" and shows a project named "ADC : FLASH". The "Component Inspector" window is open, displaying a list of components. A context menu is open over the "ADC" component, with the "Add to project" option selected.

| Component | Component Level |
|-------------|-----------------|
| 24AA_EEPROM | Low |
| 74HC164 | Low |
| 74HC595 | High |
| ADC | High |

The context menu options are:

- Add to project
- Add to project with Wizard
- Expand all
- Collapse all
- Refresh (F5)
- Delete
- Help on Component
- Profile As
- Resource Configurations

The "Commander" window on the left shows the project structure, including "Generator_Configurations", "FLASH", "OSs", "Processors", "Cpu:MKL25Z128VLK4", "Components", and "PDD". The "Build/Debug" section includes "Build (All)", "Clean (All)", and "Debug".

Configuração no CodeWarrior com PE

2) Configurar o componente

The screenshot displays the CodeWarrior Development Studio interface. The main window shows the Component Inspector for the ADC1 component. The table below represents the data shown in the 'Properties' tab:

| Name | Value | Details |
|----------------------------------|---------------------------------|----------------------------------|
| Component name | AD1 | |
| A/D converter | ADC0 | ADC0 |
| Sharing | Disabled | |
| ADC_LDD | ADC_LDD | |
| Interrupt service/event | Enabled | |
| A/D interrupt | INT_ADC0 | INT_ADC0 |
| A/D interrupt priority | medium priority | 2 |
| A/D channels | 1 | |
| Channel0 | | |
| A/D channel (pin) | ADCQ_SE8/TSIQ_CH0/PTB0/LLWU_... | |
| A/D channel (pin) signal | | |
| Mode select | Single Ended | |
| A/D resolution | 16 bits | 16 bits |
| Conversion time | 20 µs | 19.073 µs |
| Low-power mode | Disabled | |
| High-speed conversion mode | Disabled | |
| Asynchro clock output | Disabled | |
| Sample time | 0 = short | Total conv. time: high: 23.12 us |
| Internal trigger | Disabled | |
| Number of conversions | 1 | |
| Initialization | | |
| Enabled in init. code | yes | |
| Events enabled in init. | yes | |
| CPU clock/speed selection | | |
| High speed mode | This component enabled | This component is enabled |
| Low speed mode | This component disabled | This component is disabled |
| Slow speed mode | This component disabled | This component is disabled |

Annotations in the image:

- Escolher o pino:** Points to the 'A/D channel (pin)' property.
- Escolher o tempo de conversão:** Points to the 'Conversion time' property.
- Habilitar:** Points to the 'High speed mode' property under 'CPU clock/speed selection'.

Configuração no CodeWarrior com PE

3) Gerar o código do PE

The screenshot displays the CodeWarrior Development Studio interface. The main window shows the configuration for the ADC component (ADC0) in the Properties view. The configuration includes various parameters such as component name, A/D converter, sharing, ADC_LDD, interrupt service/event, A/D channels, and CPU clock/speed selection. A red arrow points to the 'Generate Processor Expert Code' button in the Components - ADC panel.

| Name | Value | Details |
|----------------------------------|--------------------------------|----------------------------------|
| Component name | AD1 | |
| A/D converter | ADC0 | ADC0 |
| Sharing | Disabled | |
| ADC_LDD | ADC_LDD | |
| Interrupt service/event | Enabled | |
| A/D interrupt | INT_ADC0 | INT_ADC0 |
| A/D interrupt priority | medium priority | 2 |
| A/D channels | 1 | |
| Channel0 | | |
| A/D channel (pin) | ADC0_SE8/TSIQ_CH0/PTB0/LLWU... | |
| A/D channel (pin) signal | | |
| Mode select | Single Ended | |
| A/D resolution | 16 bits | 16 bits |
| Conversion time | 20 µs | 19.073 µs |
| Low-power mode | Disabled | |
| High-speed conversion mode | Disabled | |
| Asynchro clock output | Disabled | |
| Sample time | 0 = short | Total conv. time: high: 23.12 us |
| Internal trigger | Disabled | |
| Number of conversions | 1 | |
| Initialization | | |
| Enabled in init. code | yes | |
| Events enabled in init. | yes | |
| CPU clock/speed selection | | |
| High speed mode | This component enabled | This component is enabled |
| Low speed mode | This component disabled | This component is disabled |
| Slow speed mode | This component disabled | This component is disabled |

Configuração no CodeWarrior com PE

3) Escreva o código no lugar apropriado

The screenshot displays the CodeWarrior Development Studio interface. The top menu bar includes File, Edit, Source, Refactor, Search, Project, MQX Tools, Processor Expert, Run, Window, and Help. The toolbar contains various icons for file operations and development tools. The main workspace is divided into several panes:

- CodeWarrior Projects:** Shows a project named 'ADC : FLASH' with sub-items like ADC_FLASH_OpenSD, Binaries, Documentation, FLASH, Generated_Code, ProcessorExpert.pe, and Driver Headers.
- Components - ADC:** Shows a tree view for 'Cpu:MKL25Z128VLK4' with 'Components' expanded to 'AD1:ADC', which includes 'AdcLdd1:ADC_LDD[ADC\ADC_LDD]' and various initialization and measurement options.
- Component Inspector - AD1:** A table showing properties for the AD1 component. The 'Internal trigger' property is highlighted with a red circle.
- main.c:** A code editor showing C code for ADC initialization and measurement. The code includes comments in Portuguese and is annotated with red circles.
- Commander:** A sidebar with 'Project Creation' and 'Build/Debug' options.
- Problems, Console, Progress, Memory:** A bottom status bar with tabs for these views.

The code in the editor is as follows:

```
/*lint -restore Enable MISRA rule (6.3) checking. */
{
    /* Write your local variable definition here */
    uint16_t IN;
    /*** Processor Expert internal initialization. DON'T REMOVE THIS CODE!!! ***/
    PE_low_level_init();
    /*** End of Processor Expert internal initialization. ***/

    /* Write your code here */
    /* For example: for(;;) { } */
    for(;;) {
        (void) AD1_Measure(TRUE); /* faz a conversão e espera pelo resultado */
        (void) AD1_GetValue16(&IN); /* coloca o resultado na variável */
    }
}
```

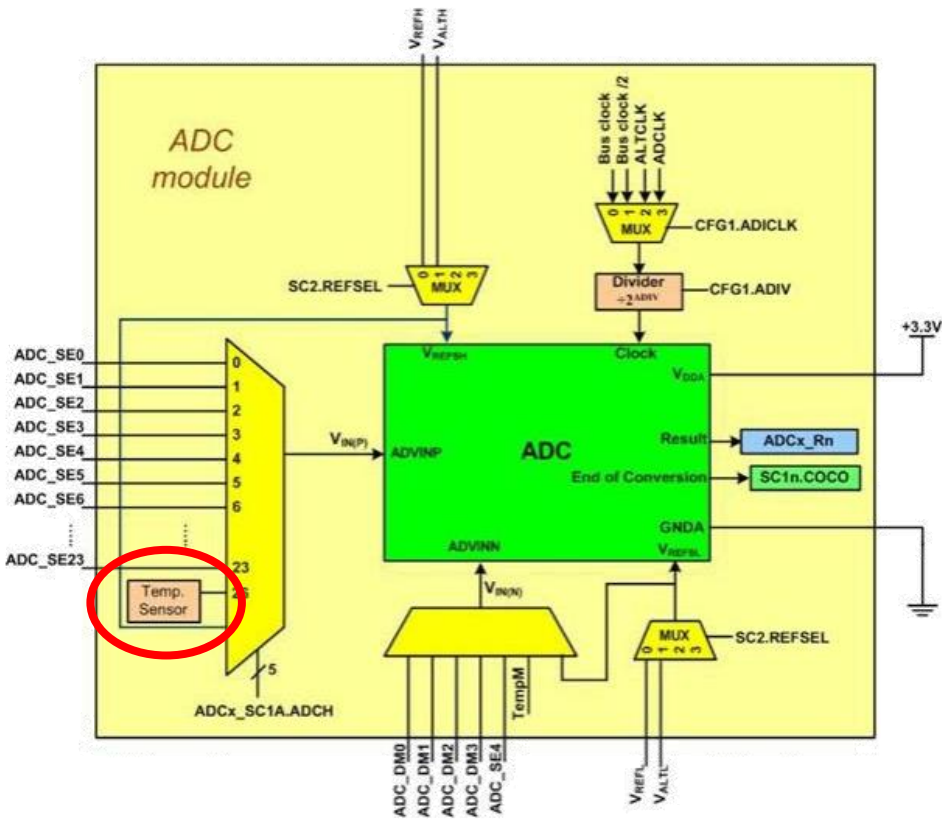


código

```
uint16_t IN; /* declara uma variável de 16 bits unsigned */  
  
for(;;) {  
    (void)AD1_Measure(TRUE); /* faz a conversão e espera pelo resultado */  
    (void)AD1_GetValue16(&IN); /* coloca o resultado na variável */  
}
```




Sensor de Temperatura



$$\text{Temp} = 25 - \left((V_{\text{TEMP}} - V_{\text{TEMP25}}) \div m \right)$$

V_{TEMP25} = tensão do sensor em 25°C

V_{TEMP} = tensão do sensor na temperatura ambiente
 m = inclinação da relação tensão vs. Temperatura

*KL25 Sub-Family Reference Manual, Rev. 3, September 2012, p. 497

| | | | | | | | |
|---------------------|---------------------|---|------|------|------|-------|---|
| m | Temp sensor slope | Across the full temperature range of the device | 1.55 | 1.62 | 1.69 | mV/°C | 8 |
| V_{TEMP25} | Temp sensor voltage | 25 °C | 706 | 716 | 726 | mV | 8 |

*Kinetis KL25 Sub-Family, Rev5 08/2014, p.30



Configuração no CodeWarrior com PE

Sensor de Temperatura no ADC

C/C++ - ADC/Sources/main.c - CodeWarrior Development Studio

File Edit Source Refactor Search Project MQXTools ProcessorExpert Run Window Help

CodeWarrior Projects

- ADC : FLASH
 - ADC_FLASH_OpenSD
 - Binaries
 - Documentation
 - FLASH
 - Generated_Code
 - ProcessorExpert.pe
 - Project_Headers
 - Project_Settings
 - SaAnalysispointsMan

Components - ADC

- Generator_Configurations
 - FLASH
- OSs
- Processors
 - Cpu:MKL25Z128VLK4
- Components
 - AD1:ADC
 - DA1:DAC_LDD
 - PDD

Commander

- Project Creation
 - Import project
 - Import example project
 - Import MCU executable file
 - New MCU project
 - New MQX-Link project
- Build/Debug
 - Build (All)
 - Clean (All)
 - Debug

Component Inspector - AD1

| Name | Value | Details |
|----------------------------------|---|---|
| A/D interrupt priority | medium priority | 2 |
| A/D channels | 1 | |
| Channel0 | | |
| A/D channel (pin) | TempSensor | |
| A/D channel (pin) signal | ADCQ_SE7b/PTD6/LLWU_P15/SPI1_MOSI/UART0_RX/SPI1_MISO | |
| Mode select | ADCQ_SE8/TSIQ_CH0/PTB0/LLWU_P5/I2C0_SCL/TPM1_CH0 | |
| A/D resolution | ADCQ_SE9/TSIQ_CH6/PTB1/I2C0_SDA/TPM1_CH1 | |
| Conversion time | CMPO_IN5/ADCQ_SE4b/PTE29/TPM0_CH2/TPM_CLKIN0 | |
| Low-power mode | Bandgap | |
| High-speed conversion mode | TempSensor | |
| Asyncho clock output | V_refsh | |
| Sample time | V_refsl | 20.58 us |
| Internal trigger | DAC0_OUT/ADCQ_SE23/CMPO_IN4/PTE30/TPM0_CH3/TPM_CLKIN1 | |
| Number of conversions | Bandgap_minus | |
| Initialization | Bandgap_plus | |
| Enabled in init. code | TempSensor_minus | |
| Events enabled in init. | yes | |
| CPU clock/speed selection | | |
| High speed mode | This component enabled | This component is enabled |
| Low speed mode | This component disabled | This component is disabled |
| Slow speed mode | This component enabled | The speed mode is disabled in the processor |

main.c ProcessorExpert.c AD1.c

```
/* Write your code here */
```

Problems Console Progress Memory

0 errors, 1 warning, 0 others