Architectures for Embedded Systems

Analog to Digital and Digital to Analog Conversion Laboratory assignments

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Academic year 2024/25

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Outline

Introduction to ADCs and DACs

- General concepts
- ESP32 aspects

Lab assignments

- Acquisition of a voltage applied by a potenciometer
- Sensing the temperature based on a analogue sensor
- Acquisition and plotting an arbitrary (band limited) signal

Questions for Autonomous Study

General aspects

- What is an ADC?
- What is a DAC?
- What is a continuous signal?
- What is a discrete signal?
- What is the sampling process in analog-to-digital conversion?
- What is the quantization process in analog-to-digital conversion?
- What is the reconstruction process in digital-to-analog conversion?
- What is the sampling rate of ADCs/DACs?
- What is the bit resolution of ADCs/DACs?
- What is the Nyquist frequency? What is aliasing?
- What is the reference voltage of ADCs and DACs?
- How does a Successive Approximation Register (SAR) ADC work?

Questions for Autonomous Study

ESP32 aspects

- How many ADCs are implemented in the ESP32-C3?
- How many ADC input channels does the ESP32-C3 provide?
- What distinguishes the “one-shot” and “continuous” modes of the ESP32 ADCs?
- How is the output of the ESP32 ADCs encoded? Natural binary? Two’s complement? Other?
- How to determine the voltage applied to the ADC from the digital sample value?
- What is the importance of the calibration process in the ADC?
- The ESP32-C3 does not provide DACs. How can a similar functionality be implemented using GPIOs (with a Delta-Sigma Modulator) or PWM?

Laboratory Assignment 1 – Potentiometer Value Acquisition (one-shot mode)

- Connect a 10kΩ potentiometer to an ADC input channel, applying to the converter a voltage between 0 a +3.3V (it is fundamental to draw the schematic in the log book, before connecting the potentiometer)
- Based on the ADC “oneshot_read” example, write an application that acquires the voltage at the potentiometer cursor and displays it on the screen
- Test the program with different values of the ADC attenuation parameter
- Sources of information
  - Datasheet: ESP32-C3 Technical Reference Manual – Chapter 34.2 (SAR ADCs)
  - API description: https://docs.espressif.com/projects/esp-idf/en/v5.4/esp32c3/api-reference/peripherals/adc_oneshot.html
  - Example: C:\Espressif\frameworks\esp-idf-v5.4\examples\peripherals\adc\oneshot_read

Laboratory Assignment 2 - Analog Temperature Sensor (one-shot mode)

- Connect a LM335 temperature sensor to an ADC input channel (it is fundamental to draw the schematic in the log book, before connecting the sensor)
- Based on the ADC “oneshot_read” example, write an application that acquires the voltage at the sensor output and displays the corresponding temperature on the screen
- Include calibration capabilities and select an appropriate value for the attenuation parameter
- Sources of information
  - Datasheet: LM335 Precision temperature sensors (https://www.st.com/resource/en/datasheet/lm135.pdf)
  - API description: https://docs.espressif.com/projects/esp-idf/en/v5.4/esp32c3/api-reference/peripherals/adc_calibration.html

Laboratory Assignment 3 – Acquisition of an Arbitrary (band limited) Signal (continuous)

- Select an appropriate ADC channel and apply a sinusoidal signal comprised between 0 and $V_{ref}/2$ and a frequency corresponding to one-tenth of the ADC sampling rate
- Insert the protection circuit (1k Ω resistor + 3.3V Zener diode) between the generator and the ADC
- Based on the ADC "continuous_read" example, write an application that acquires the signal and sends "chunks" of adjacent samples to the PC to be plotted with a tool of your choice
- Repeat the acquisition with sinusoidal signals with the following frequencies:
  - One quarter of the ADC sampling frequency
  - Equal to the ADC sampling frequency
  - Twice the ADC sampling frequency
- Sources of information
  - API description: https://docs.espressif.com/projects/esp-idf/en/v5.4/esp32c3/api-reference/peripherals/adc_continuous.html
  - Example: C:\Espressif\frameworks\esp-idf-v5.4\examples\peripherals\adc\continuous_read

Final Remarks

- At the end of this week, you should be familiar with the:
  - Analog to digital and digital to analog conversion basic concepts and supporting components
  - Interfacing ESP32 with the “analog world”
  - Programming of ESP32 ADC modules