CMSIS-DSP FFT with Real-Time Voltage Monitoring

Overview:

ADC polling, FFT analysis, and data visualization.

Presenter:

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Microsoft: VC++ Libraries, Conformance

DellEMC: Network Protocol, DevOps Consultant

Bibliography

- Introduction of Algorithms, 3rd ed., CLRS.
- Algorithms in C++, Sedgewick, 1992, Addison-Wesley.
- The Art of Electronics, 3rd ed.,Horowitz, Hill
- College Algebra, M. Richardson, 1947
- Embedded Systems Series, J. Valvano
- ST Electronics, HAL and CMSIS, STM32F401RE docs.
- Keil CMSIS Documentation, ARM::CMSIS Pack

Start Demo 1: Polling the System for Voltage Readings

- Use of ADC to convert analog voltage signals into digital values.
- Sampling real-time voltages, storing them in buffers, and preparing them for FFT analysis.
- Key Concepts: ADC initialization and polling using STM32CubeMX, HAL (Hardware Abstraction Layer).

Demo 2: Fast Fourier Transform (FFT)

- Explanation of FFT and how it breaks down a time-domain signal into its frequency components.
- Magnitude Conversion: Converting the FFT results into magnitudes for further processing.
- CMSIS-DSP library provides optimized math routines for embedded systems.

CMSIS/DSP Libraries (part 1)

- Basic Math Functions: Simple arithmetic and trigonometric operations.
  - Example: Vector addition, where two arrays of numbers are element-wise added together.
- Fast Math Functions: Optimized math functions for performance.
  - Example: Fast approximation of a square root using a look-up table for quick calculation.
- Complex Math Functions: Operations for complex numbers.
  - Example: Complex number multiplication

CMSIS/DSP Libraries (part 2)

- Filtering Functions: Implementing FIR, IIR filters, etc.
  - Example: FIR (Finite Impulse Response) filter, which applies a weighted moving average to a signal, reducing noise.
- Matrix Functions: Matrix arithmetic and manipulations.
  - Example: Matrix multiplication, multiplying two matrices to compute their product, commonly used in signal and image processing.
- Transform Functions: Transforms like FFT and DCT.
  - Example: FFT (Fast Fourier Transform) for converting a signal from the time domain to the frequency domain.

CMSIS/DSP Libraries (part 3)

- Motor Control Functions: Algorithms for controlling motors.
  - Example: PID (Proportional-Integral-Derivative) controller for adjusting motor speed based on error feedback.
- Statistical Functions: Basic statistics like mean and standard deviation.
  - Example: Mean calculation, which computes the average of a data set.
- Support Functions: Miscellaneous helper functions.
  - Example: Copying vectors, where one array is copied into another.

CMSIS/DSP Libraries (part 4)

- Interpolation Functions: For estimating values between known data points.
  - Example: Linear interpolation, which estimates values on a line between two known points.
- Support Vector Machine (SVM) Functions: Machine learning algorithms.
  - Example: SVM classification, used to classify data points into categories by finding the optimal boundary (hyperplane) between them.
- Bayes Classifier Functions: Probabilistic classifier algorithms.
  - Example: Naive Bayes classifier, which assigns class labels to data points based on conditional probabilities.
- Distance Functions: Calculate the distance between two points in different ways.
  - Example: Euclidean distance, which measures the straight-line distance between two points in Euclidean space

Keil CMSIS-DSP Pack Contents

- CMSIS\Documentation\DSP: DSP Library documentation.
- CMSIS\DSP\DSP_Lib_TestSuite: Test suite for DSP library functions.
- CMSIS\DSP\Examples: Example projects demonstrating usage of DSP functions.
- CMSIS\DSP\Include: DSP library header files.
- CMSIS\DSP\Lib: Precompiled binaries of DSP library.
- CMSIS\DSP\Projects: Projects to rebuild DSP library binaries.
- CMSIS\DSP\Source: Source code of DSP library functions.

Printing Data Using UART

- UART for data transmission.
- Printing FFT and magnitude results to a terminal using printf and HAL_UART_Transmit.
- Tools: terminal (Eclipse Marketplace or Valvano's TexaS Com Port Reader) used to display results.
- ST-Link, Device Manager, COM port properties

Priority Queue and Efficient Sorting

- Priority Queue: Usage for organizing magnitude data.
- Mention the buffer integration, reusing existing buffers for efficient memory usage.
- Heap Sort: Discuss how this sorting technique helps maintain priority ordering of data.

Graph Representation of FFT Data

- Graph Structure: Explanation of using a graph to represent FFT peaks and valleys.
- Adjacency Lists: Representing edges using bitvectors, adding edges based on peaks and valleys.
- Importance of efficient data representation for embedded systems.

General Programming Tips in C

- Globals in C: Why using globals might seem counterintuitive but necessary for managing limited stack space in embedded systems.
- Mention other best practices in memory management for resource-constrained environments.
- Data Driven Design, generic reuse not a priority.

Key Takeaways

- Recap the project workflow: ADC sampling, FFT processing, magnitude conversion, and data visualization.
- Discuss the overall flow of the project and its practical application in embedded systems.
- Encouragement to explore further into CMSIS-DSP and embedded programming.