Vocal Motion

Endpoint device for the Artificial Intelligence Internet of Things

ELECOMP Capstone Design Project 2023-2024

Sponsoring Company:

XMOS
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Company Overview:

XMOS is a fabless semiconductor company, headquartered in Bristol in the UK.

Our mission is to change the way systems are deployed on silicon – disrupting system-on-chip economics and time to market by enabling embedded software engineers to create custom SoC solutions simply by loading software onto our uniquely flexible and accessible hardware platforms.

Our xcore® technology unleashes the creativity of embedded software engineers to deliver solutions to an ever-widening range of smart things that span the primary IoT pillars of consumer, industrial and automotive.

Technical Director:

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Project Motivation:

XMOS is currently shipping our 3rd generation of silicon, xcore.ai. Starting with our first generation there have been use cases in motor control and other industrial areas. In our second generation of silicon we started supporting various AI workloads. The third generation of chip adds a significant boost in AI processing power while retaining the deterministic, responsive IO processing that made our first generation so successful. This project will create a tangible demonstration of this claim to support both marketing and direct sales opportunities in the future.

The team will design a PCB with an XMOS chip and other components for local speech recognition and motor/device control. They will also develop software to integrate these functionalities. Time permitting, additional AI capabilities like predictive maintenance may be explored, along with potential networking or connectivity enhancements. The project aims to create an advanced AIIOT device showcasing the team's engineering expertise and innovation.

Anticipated Best Outcome:

If the team achieves the ABO then they will have produced a PCB with:

- An xcore.ai chip
- At least one actuator
- At least one microphone
- Additional test points and a debug header

In addition to the hardware deliverable the team will also integrate and create (as needed) the software components required to demonstrate end-to-end functionality of translating a user's verbal request into an action (i.e. "speed up" commanding a motor to change speeds, or "lights on" flipping a relay).

Beyond the ABO there is an opportunity to add more sensors / actuators, add connectivity, and to add more intelligence (for example, predictive maintenance).

Project Details:

Overall system concept:

The project's main goal is to create a tangible demonstration of XMOS's xcore.ai chip capabilities, showcasing its AI processing power while maintaining deterministic and responsive IO processing. The team will design a Printed Circuit Board (PCB) integrating the xcore.ai chip and other components for local speech recognition and motor/device control. They will also develop software to enable end-to-end functionality, translating a user's verbal request into an action, such as controlling a motor or turning on lights. The project may also explore additional AI capabilities like predictive maintenance and potential networking enhancements if time permits.

Block Diagram:

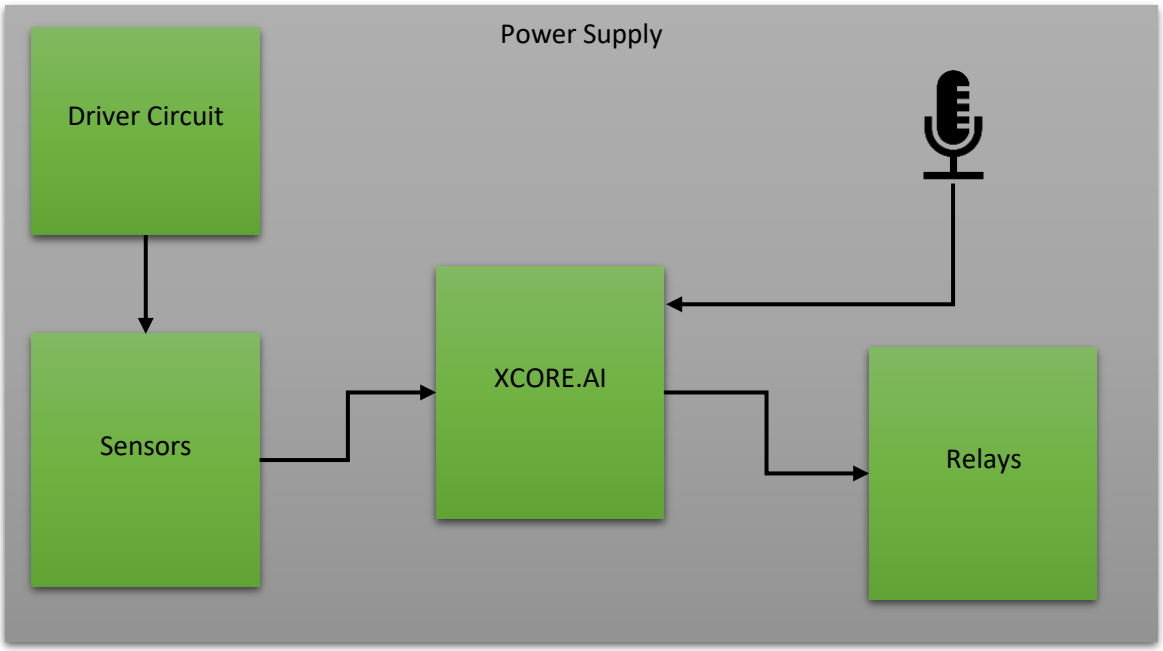

Figure 1 System block diagram. Note sensors include, but are not limited to: motor position and current draw

Hardware/Electrical Tasks:

1. **Schematic Design:** Creating a detailed schematic diagram of the PCB, including the connections between the xcore.ai chip, actuators (e.g., motors or relays), microphones, and any other necessary components.
2. **Board Layout:** Designing the physical layout of the PCB, arranging the components in an optimized and space-efficient manner. Careful consideration should be given to signal integrity, power delivery, and thermal management.
3. **Power Electronics:** Implementing the power supply circuitry for the PCB, ensuring stable and efficient power distribution to all components. This may involve selecting appropriate voltage regulators, capacitors, and power management solutions.
4. **Actuator Integration:** Integrating the actuators (e.g., motors or relays) into the PCB design and ensuring they are properly controlled by the xcore.ai chip. This might involve using power transistors or relay drivers to interface with the actuators.
5. **Microphone Integration:** Integrating the microphone(s) into the PCB and configuring the connections to enable speech recognition and audio input for the AI processing.
6. **Debug Header:** Adding test points and a debug header to facilitate testing and troubleshooting during the development and production phases.

7. **Power and Signal Integrity Analysis:** Performing simulations or calculations to ensure the power delivery and signal integrity meet the design requirements, minimizing noise and interference.
8. **Component Selection:** Selecting appropriate components (e.g., resistors, capacitors, connectors) based on their specifications and compatibility with the xcore.ai chip and other elements of the design.
9. **Iterative Design Refinement:** If necessary, refine the PCB design based on testing results and feedback, to improve performance and address any identified issues.
10. **Documentation:** Preparing detailed documentation, including the PCB schematics, bill of materials (BOM), design files, and any relevant technical information for future reference and production.

Firmware/Software/Computer Tasks:

1. **Firmware Development**: Developing the firmware that runs on the xcore.ai chip. This firmware will be responsible for managing the AI processing, interfacing sensors and actuators, handling speech recognition, and controlling motor/device operations.
2. **Speech Recognition Software:** Create an example set of commands for your project using Sensory Voice Hub.
3. **Actuator Control Software:** Developing software to control the actuators based on the received commands from the speech recognition module. This software should ensure smooth and accurate motor/device control.
4. **Microphone Interface Software:** Implementing software to interface with the microphones and process the audio input, preparing it for speech recognition.
5. **Real-Time Processing:** Ensuring that the firmware and software are optimized for real-time processing to achieve low latency and quick response times for AI and motor/device control operations.
6. **Software Integration:** Integrating the firmware and software components seamlessly with the hardware to achieve end-to-end functionality for translating user verbal requests into actions.
7. **Software Interoperability:** Ensuring that the software is designed to work cohesively with the hardware and that the APIs and libraries used are compatible with the xcore.ai chip and other components.
8. **Software Testing and Validation:** Thoroughly testing the firmware and software to verify their correctness, performance, and reliability. This includes conducting unit testing, integration testing, and system testing.
9. **Software Documentation:** Preparing comprehensive documentation for the firmware and software, detailing their functionalities, usage, and interfaces. This documentation will aid in future development, maintenance, and troubleshooting.
10. **Flexibility for Future Enhancements:** Designing the firmware and software in a modular and scalable manner, allowing for easy integration of additional AI capabilities, networking enhancements, or new sensor/actuator support in future iterations.

Composition of Team:

1 Electrical Engineers & 1 Computer Engineers

Skills Required:

Electrical Engineering Skills Required:

- Schematic design
- Board layout
- Power electronics
- Basic knowledge of power transistors and or relays

Computer Engineering Skills Required:

- Microcontroller or FPGA experience
- Strong C/C++ knowledge preferred
- Experience using a third-party library or API
- Knowledge of multicore / multiprocessor architectures

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

By demonstrating both the AI and control capabilities of the xcore.ai processor in a user-friendly development kit XMOS can expand its customer base. The kit designed in this capstone project (or one derived from the delivered design files) may be distributed through sites such as DigiKey or Adafruit which will also help XMOS engage with the active hobbyist/maker community and signal to this community that they can use XMOS hardware for more than just audio projects.

Broader Implications of the Best Outcome on the Company's Industry:

The ABO would help the Industrial Internet of Things (IIoT) by significantly reducing costs and enabling wider adoption. Its AI capabilities allow for on-device data processing, real-time analytics, and predictive maintenance. This leads to faster response times, lower latency, and more efficient operations. Additionally, the chip's edge computing capabilities improve security and energy efficiency. With adaptive automation and enhanced security measures, the IIoT can thrive across various industries, bringing about a transformative impact on industrial processes and connectivity.