

Design and Implementation of a Low-Cost FPGA-Based Educational Kit

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Overview

Teaching hardware design requires specialized platforms that are often expensive and complex to use. This work addresses these limitations by proposing a low-cost FPGA-based educational board with simplified hardware and software integration. The goal is to reduce costs and improve usability, enabling more accessible and scalable hands-on teaching of digital design.

Key design aspects:

- Low-cost solution enabling per-student deployment
- Reduced system complexity and improved usability
- Integrated hardware and software environment
- Reproducible and simplified development workflow

Hardware

The platform is based on the Lattice iCE40 UltraPlus (iCE40UP5K) FPGA, selected for its low cost, availability of unofficial open-source toolchains, and suitability for small-scale educational designs. The device provides 5,000 LUTs, offering sufficient resources for simple digital design tasks.

The proposed hardware architecture consists of an FPGA core, a programming interface, and a set of simple user peripherals. Communication with a host computer allowing both development-time programming and runtime interaction. The overall architecture emphasizes simplicity, low cost, and educational flexibility.

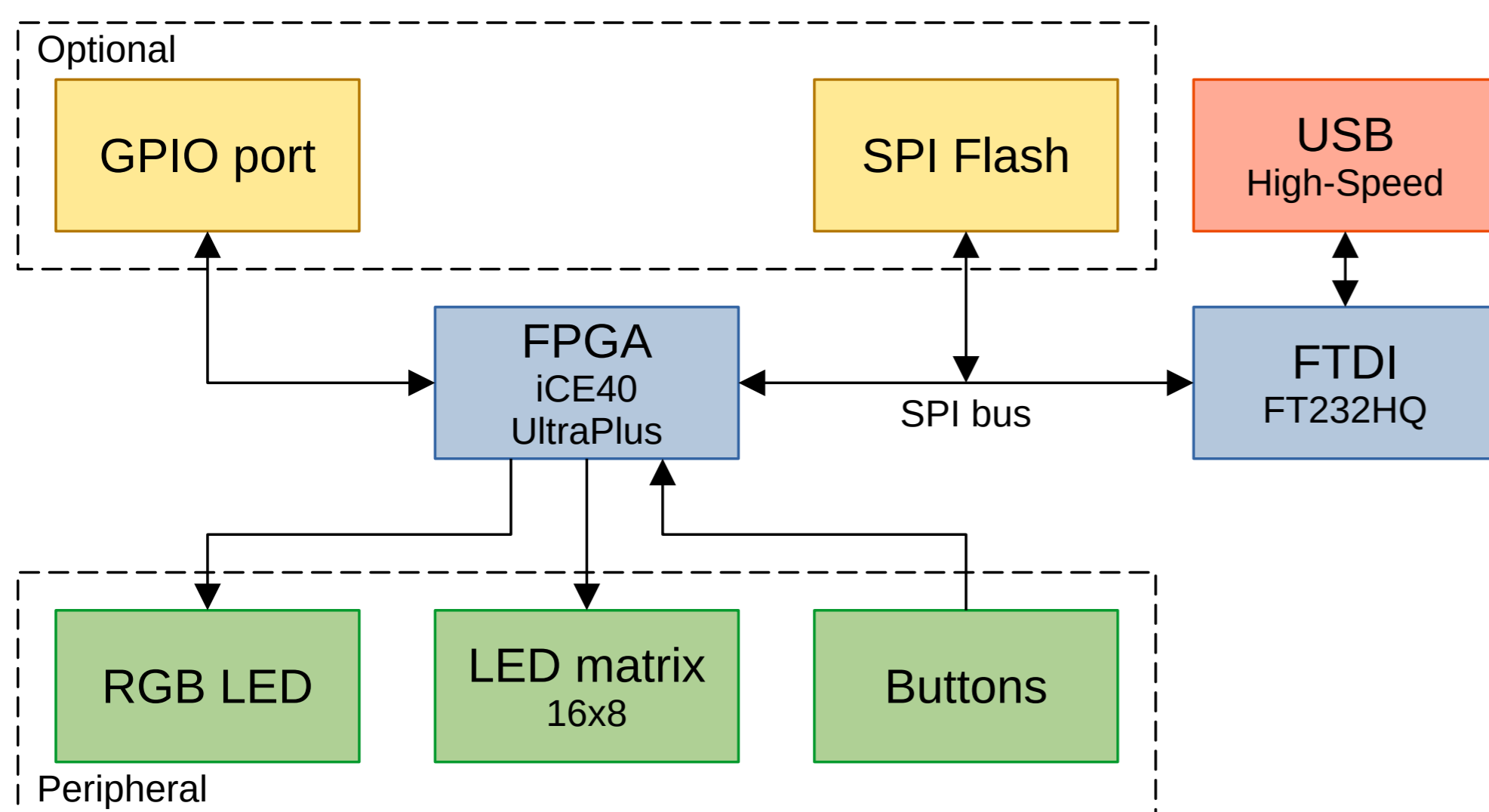


Figure 1. System block diagram of the FPGA board

The LED matrix serves as the primary user output device and is designed to demonstrate timing, multiplexing, and basic digital control principles.

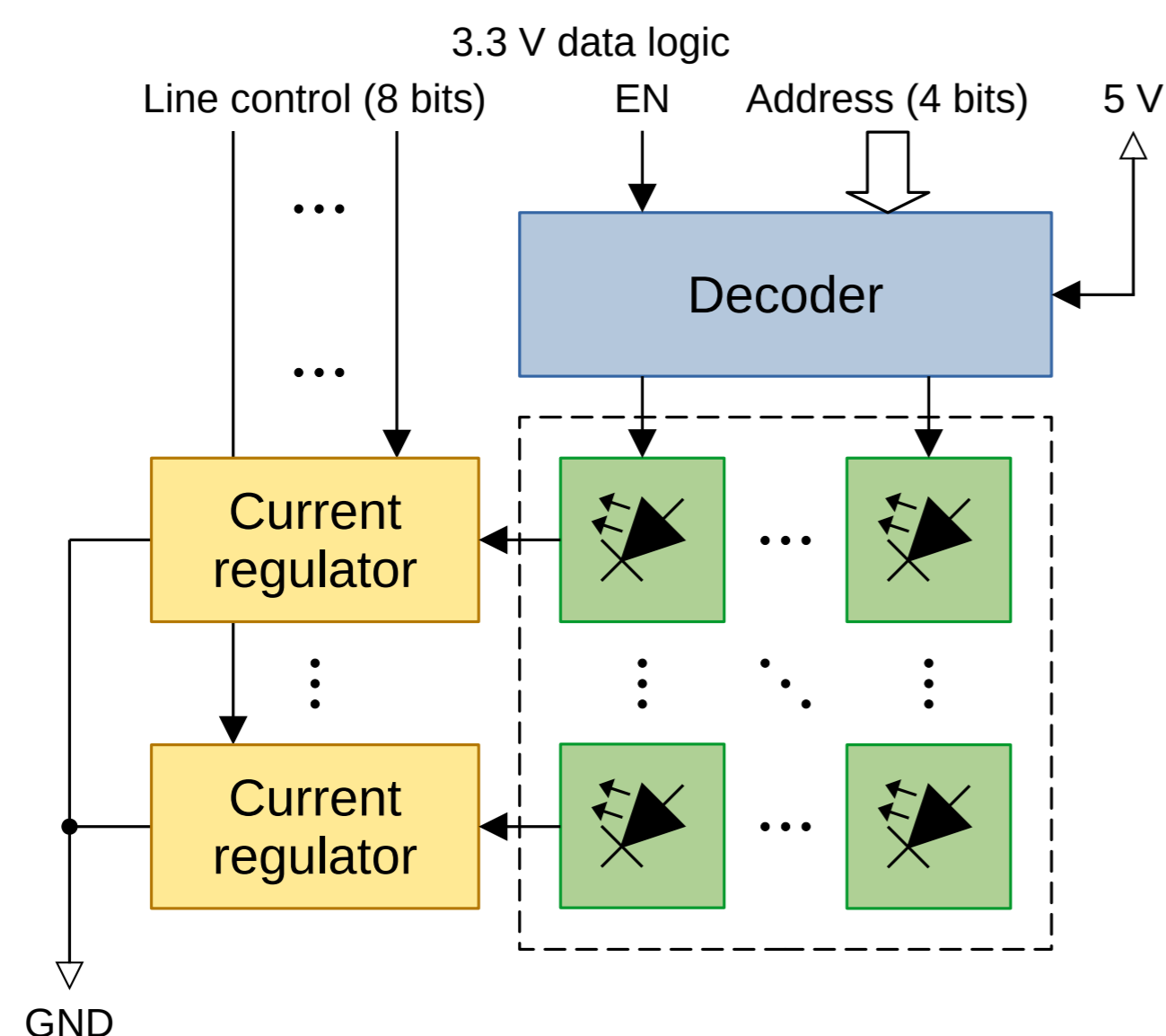


Figure 2. Simplified LED matrix control block diagram of the FPGA board

Software

The development flow is based on the Lattice Radiant toolchain and simulation using QuestaSim. Compared to previously used FPGA platforms, Radiant provides faster synthesis and lower system requirements, making it more suitable for student environments.

To simplify usage and ensure reproducibility, a custom support tool was developed. It automatically generates project configurations from source files, eliminating the need to submit vendor-specific project.

The tool provides a text-based user interface, enabling easy operation both locally and over SSH, without requiring a graphical environment.

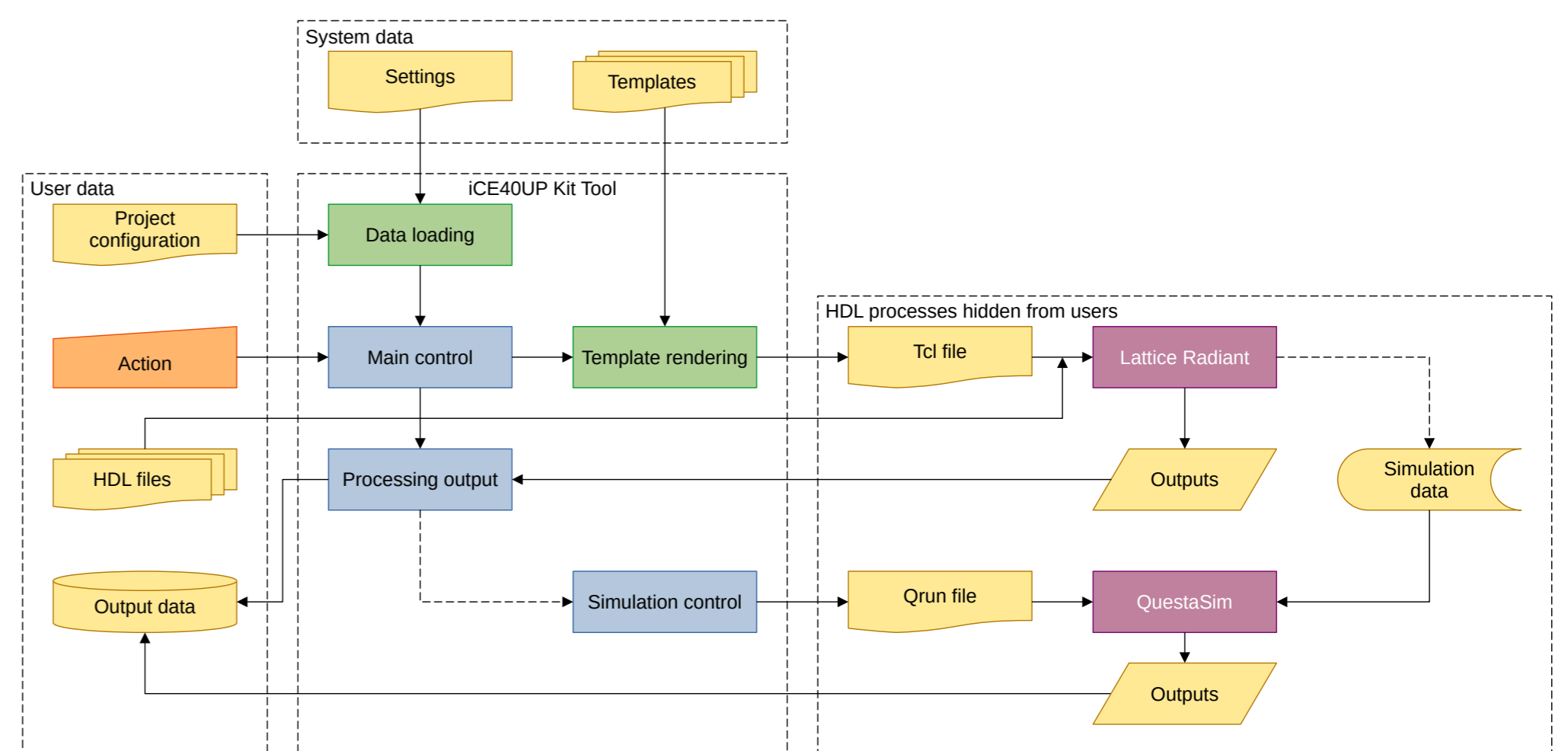


Figure 3. Simplified data flow of the support tool (iCE40UP Kit Tool)

Results

The prototype PCB boards have been successfully manufactured and tested. The price is €26.50 (650 CZK) per unit, which is significantly less than the current solution.

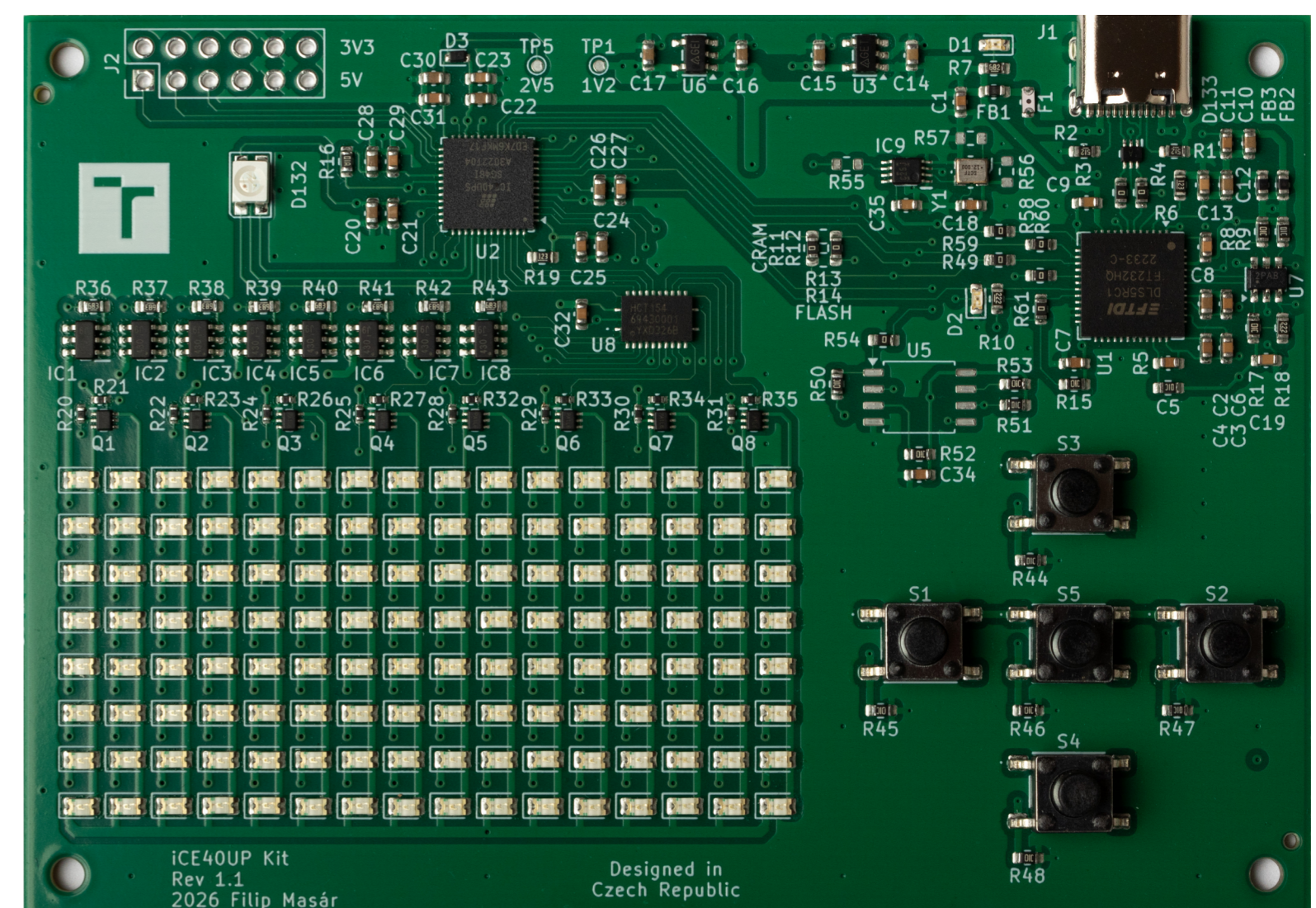


Figure 4. Top view of the proposed PCB design

The results, including four representative example applications, confirm that the proposed platform is both low-cost and sufficiently powerful for typical educational use.

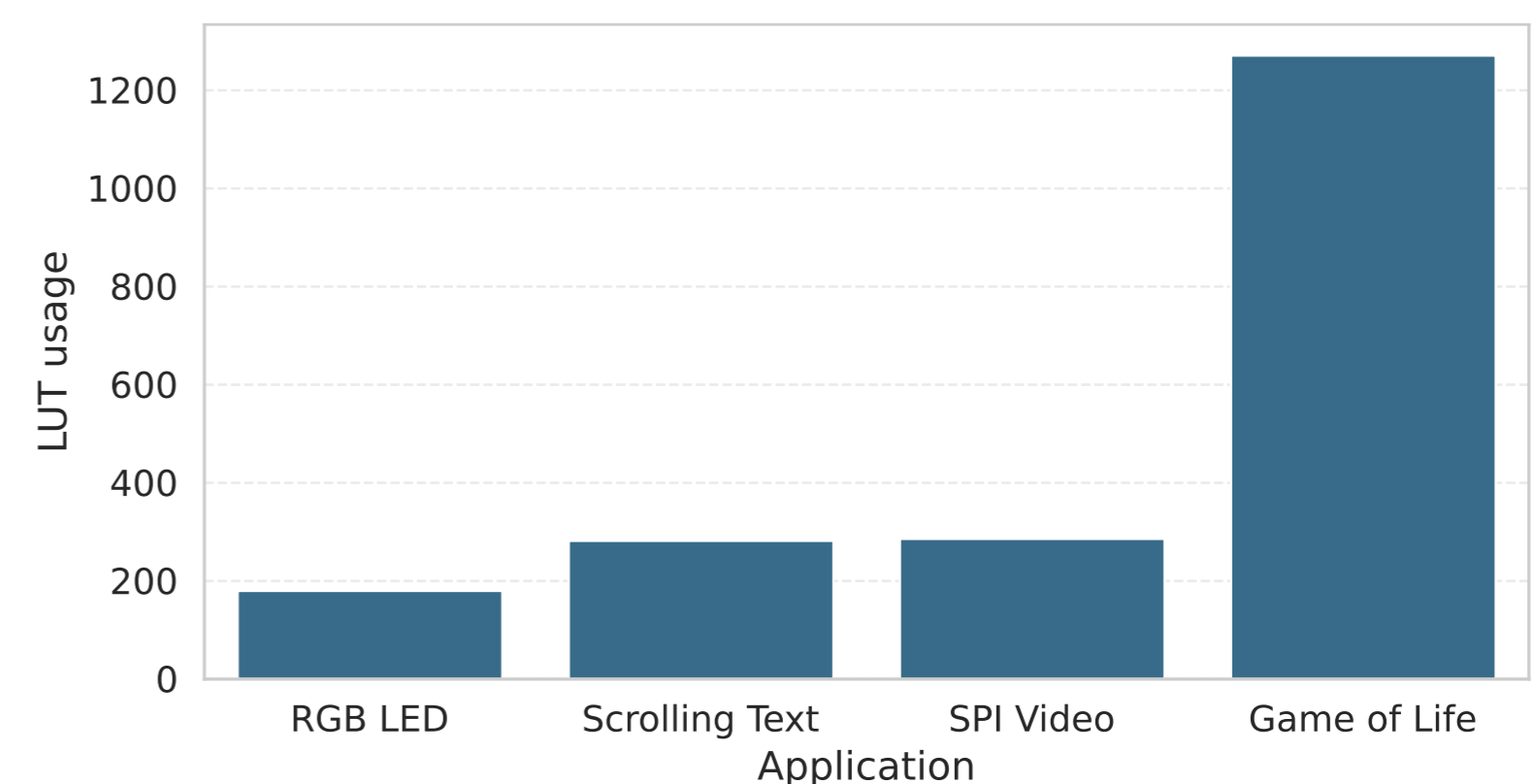


Figure 5. FPGA LUT Utilization per application

Conclusion

The proposed solution is a comprehensive, ready-to-use platform designed for hands-on education with a user-friendly interface. Its low cost, which is 8 to 10 times lower than the current solution, provides the opportunity for large-scale deployment so that each student has access to it.