B5: Enigma18 | Amelia, **Nancy**, Tanisha

APPLICATION

- Modernized implementation of WWII Enigma machine
- FPGA and custom PCB

USE CASE

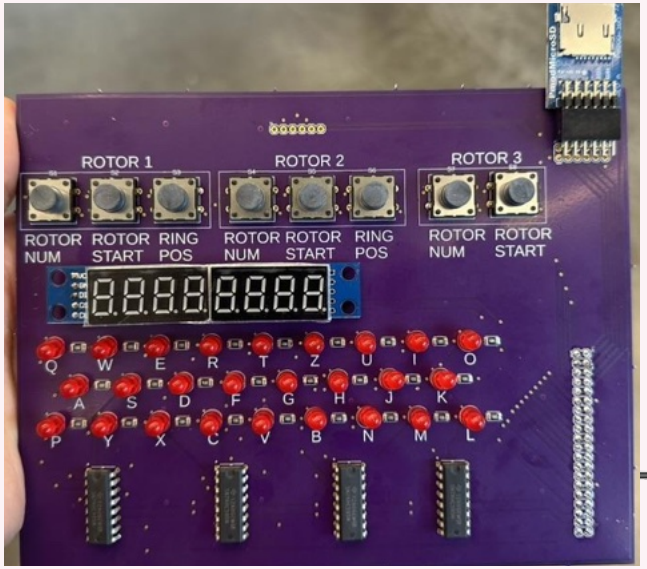
- Educate about **cryptography** through hands-on encryption and decryption
- For use in museums and classrooms (**compact**, interactive, open-source)

Use-Case Requirements

Rotors

Lampboard

Keyboard

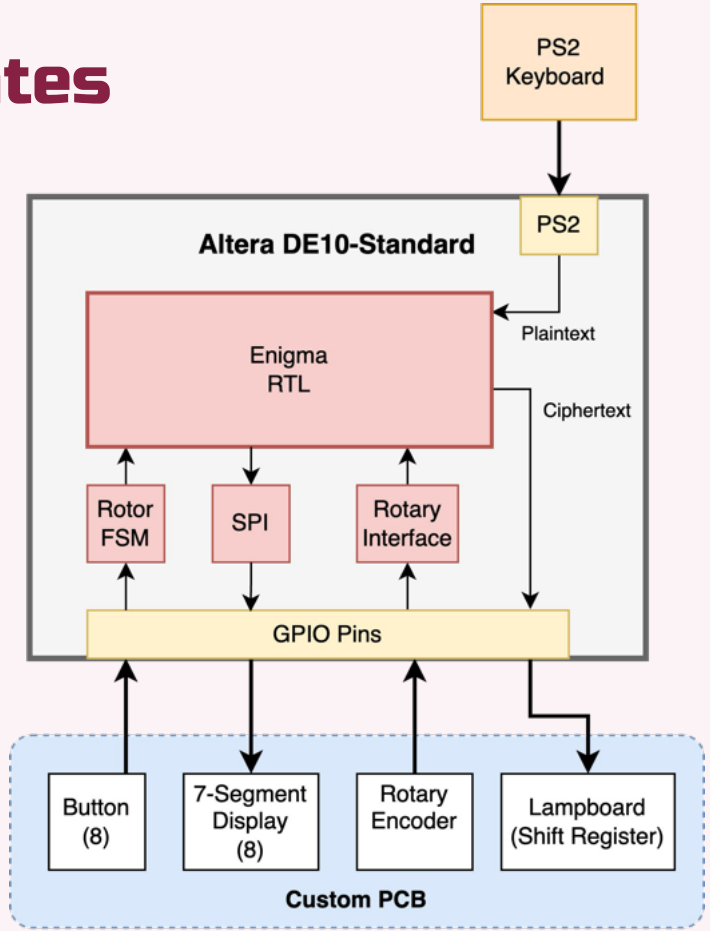


Use-Case → Design Requirements

USE-CASE	DESIGN REQUIREMENT
I/O to represent all **26** letters of alphabet	• **26** LEDs and **26** keys
Compact size to be **held in two hands**	• Fit on DE10-Standard (**66mm x 130 mm**) header pins
100% of computation and interfacing should be done on FPGA	• Must use **<= 36 GPIO pins** (not including GND, 3.3V, 5V)
Power consumption only requires **1 standard wall outlet**	• FPGA **12V** DC power adapter • All peripherals operate at **3.3V** from GPIO pins

System Specification Updates

- Altera DE-10 Standard FPGA
- 1 rotary encoder
- PS/2 Keyboard
- MicroSD card
- Custom housing

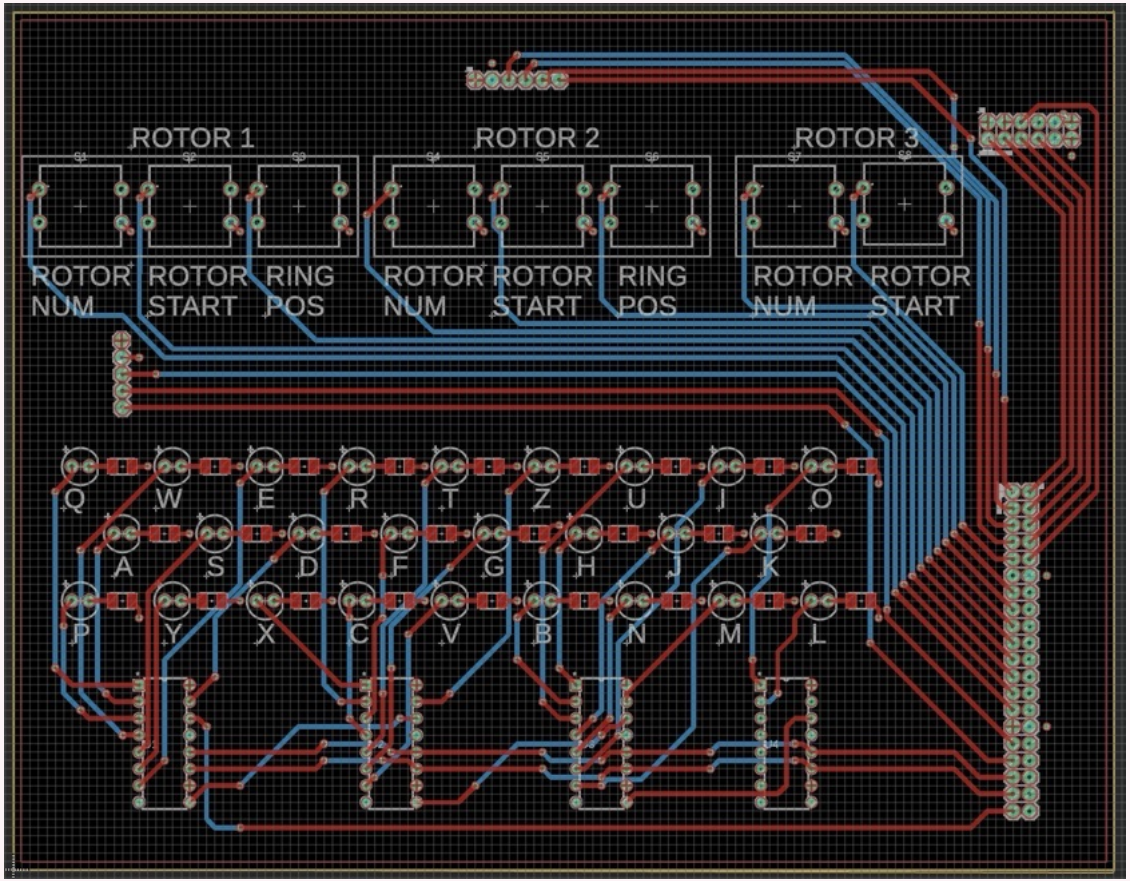


Welfare Considerations

- **GLOBAL**: Open-source, hands-on, and accessible to different backgrounds
- **CULTURAL**: Balance between highlighting technological achievement & acknowledging historical WWII implications
- **ECONOMIC**: Open-source RTL & sourced PCB domestically
- **ENVIRONMENTAL:** Repurposed keyboard & minimal custom casing

PCB Layout

- Redesigned PCB
- User-friendly
- Historically accurate layout
- Power/safety considerations (3V3 compatibility, wide traces)



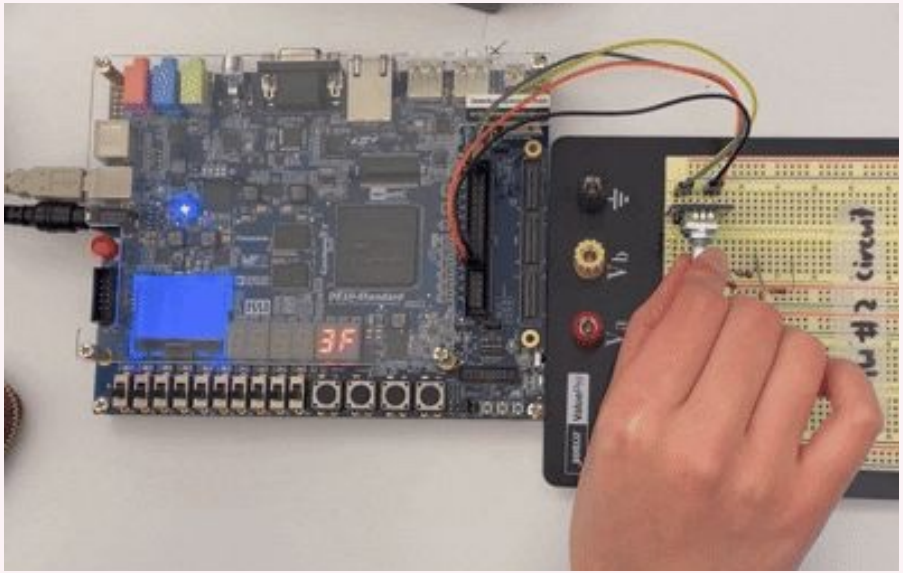
PCB Testing, Verification, Validation

AREA	TEST METHOD	DESIGN REQUIREMENT	
PCB Design	Design Rule Check	Verified design meets manufacturing requirements with **0 errors**	✅
	Electrical Rule Check	Verified power and ground connections with **0 errors**	✅
PCB Fab	Continuity test	Continuity test on multimeter, ensure proper fabrication with **0 open circuits** throughout board	✅
	Voltage measurement	Verified voltage levels at **every** connection for all LEDs, resistors and GPIO (rotary encoder, FPGA header, shift registers)	✅
	Trace Verification	Validated **100%** of traces by powering PCB and validating output voltage levels against schematic (e.g. LED on, logical high)	✅

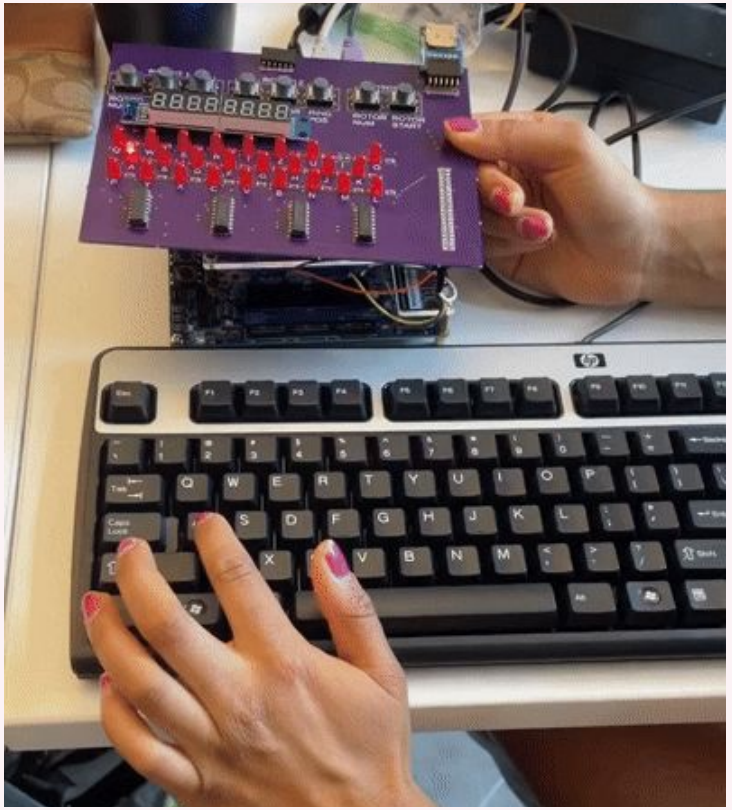
RTL Progress

Task	Status
Fully replicated Enigma **encryption** + verified with simulator	✅
Functional **PS2 keyboard** protocol implementation	✅
Basic **I/O manipulation** of rotor settings	✅
Rotor settings integrated with **rotary encoder**	✅
SPI protocol for **seven segment display**	✅
Shift register integration for lampboard	✅
Full integration + verification with custom PCB	

Final Solution Testing



Rotary Encoder Demonstration



Lampboard Demonstration

Final Solution with Housing

Isometric Back View

Isometric Front View

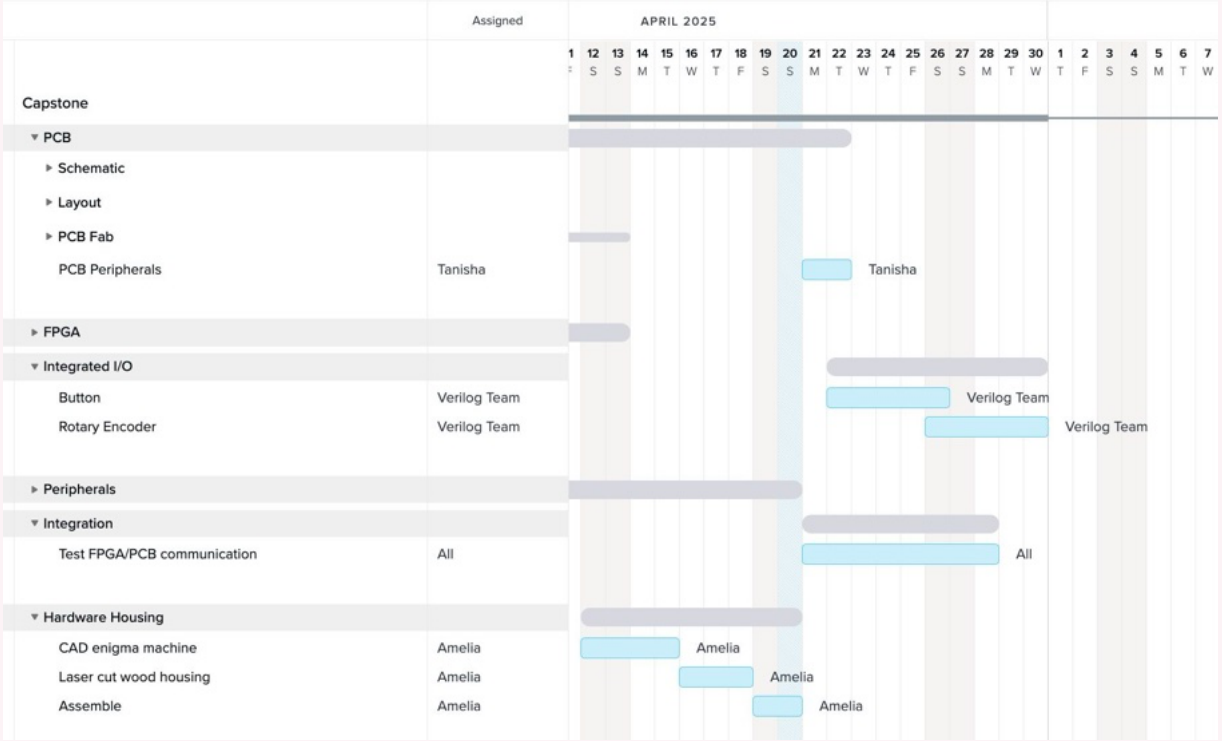
RTL Testing, Verification, Validation

- Online Enigma simulator as ground truth
- Passing test = 100% accurate encryption or peripheral output

Keyboard CPM	Encryption Accuracy
<= 100	100%
200-350	~60%

AREA	METHOD	DESIGN REQUIREMENT	
Synth	Peripheral unit tests	**Lampboard:** Lights up random sequence of **50 letters** **Keyboard:** Type continuously at set BPM for **2 minutes**	✅
	Integrated user tests	Test fully integrated product on **5 people** (manipulating all inputs)	➡️ SOON
Sim	Constrained Random Tests	Rotor logic: Input **500** randomized plaintext → ciphertext characters **20** randomized Enigma settings	✅
		Keyboard: **20** randomized **200** inputs with matrix scanner algorithm	✅

Project Management



EMBEDDED TEAM :
Tanisha + Nancy

VERILOG TEAM :
Amelia + Nancy