Interim Internship Report

(July - November 2025)

Under Supervision of,

Prof. Manish Jain
Teaching Professor
Center for Creative Learning, IIT, Gandhinagar

By,

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Acknowledgement

I would like to express my sincere gratitude to **Prof. Manish Jain**, **Center for Creative Learning**, **Indian Institute of Technology Gandhinagar**, for providing me with this invaluable opportunity and for his continuous mentorship and guidance throughout my internship. I am equally thankful to the entire **CCL team** and the **IIT Gandhinagar** community for fostering such a creative, collaborative, and inspiring learning environment that has significantly enriched my experience.

I also extend my heartfelt thanks to the **Department of Information and Communication Technology, School of Technology, Pandit Deendayal Energy University**, for facilitating this internship and supporting my professional growth. I am particularly grateful to **Dr. Sundar Manoharan**, Director General, **Dr. Anirban Sircar**, Director, School of Technology, and **Mr. Paawan Sharma**, Head of Department, ICT, for their constant encouragement and academic guidance.

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Executive Summary

- Currently interning at the **Center for Creative Learning (CCL), IIT Gandhinagar**, contributing to **Project Madhava**, an initiative to build computing concepts from first principles using hands-on, modular hardware.
- Working on a range of **digital electronics and embedded systems modules**, including clocks, calculators, multiplier circuits, LED displays, and several assembly-based ATmega328 projects such as keyboard–LCD interfacing, interrupt-driven clocks, and graphical LCD applications.
- Actively contributing to the ongoing development of a **breadboard-based 8-bit processor**, involving ALU design, instruction decoding, address control, and memory interfacing.
- Participating in **outreach and demonstrations** at national platforms like Akhil Bhartiya Shiksha Samagam, ESTIC, and Semicon, engaging with educators, policymakers, and scientific leaders.
- Strengthening skills in **assembly programming, circuit debugging, communication protocols, and ICT-aligned system design**, with continued work planned on extending Project Madhava modules and improving their educational integration.

1. Introduction

Innovation often emerges at the intersection of curiosity, opportunity, and mentorship. My journey from working with STEMbotix, Gandhinagar to becoming a part of the Center for Creative Learning (CCL) at the Indian Institute of Technology Gandhinagar (IITGN) reflects this very fusion. What began as an internship focused on embedded systems gradually evolved into an opportunity to contribute to one of the most inspiring educational initiatives in the country, under the mentorship of Prof. Manish Jain (Teaching Professor).

In May 2025, I began my internship at STEMbotix as an Embedded Systems and Electronics Intern. During this phase, I worked on bare-metal programming of microcontrollers such as STM32 and AVR, explored low-level hardware architecture, and volunteered in STEM workshops. In mid-June 2025, I was assigned a unique task—developing a barebone ATmega-based system using assembly language as a part of a collaborative effort with CCL IITGN. This project was intended to be the foundation for teaching basic electronics, digital logic, and computer architecture to students of ITI, Diploma, and Degree curriculum.

During my assigned project demonstration, Prof. Manish Jain shared his vision of building a complete 8-bit computer from scratch, using only fundamental electronic components and breadboards. This idea instantly resonated with my thoughts, as I was familiar with Ben Eater's series of 42 videos building a computer from first principles of architecture, I had previously studied computer architecture in depth at Pandit Deendayal Energy University (PDEU) by Dr.

Ankur Changela. Recognizing this alignment of interest and skill, Prof. Jain offered me an internship position in July 2025 at CCL, IIT Gandhinagar.

Since July 2025, I have been working at the CCL, IIT Gandhinagar, contributing to the development of educational modules and an 8-bit computer architecture using assembly, logic circuits, and embedded systems. This report documents my experiences, contributions, learnings, and the profound impact it creates on CCL and PDEU.

2. The Center for Creative Learning and My Role

2.1 About the Center for Creative Learning (CCL)

The Center for Creative Learning (CCL) was established in April 2017 at IIT Gandhinagar with the vision of nurturing scientific temperament and creativity in students and educators across India. Founded by Prof. Manish Jain, who previously worked with renowned science communicator Arvind Gupta, CCL focuses on reigniting curiosity through hands-on exploration and joyful learning.

Over the years, CCL has:

- Engaged **over 5 lakh online participants**,
- Conducted **hands-on STEM workshops for more than 20,000 teachers and engineering faculty**, and
- Interacted with **over 50,000 students across India**.

CCL designs and creates:

- Scientific toys, puzzles, STEM art, math-based installations, and interactive exhibits,
- Demonstrations for science centers, exhibitions, and classrooms,
- Educational videos, newspaper articles, research papers, and teacher training content.

Its work extends to national-level policy and educational development, serving on committees such as:

- National Focus Group on Mathematics and Computational Thinking (NEP 2020),
- Committee on Toy-based Pedagogy by the Ministry of Education,
- NCERT committees for foundational numeracy and curriculum development.

2.2 My Role at CCL

After joining CCL in July 2025, my role focused primarily on the development of hands-on educational modules—designing an **8-bit computer from scratch using breadboards, logic ICs, and assembly language**. My key responsibilities include:

- **Microcontroller and Bare-Metal Programming:** Implementing assembly-level programs on ATmega microcontrollers, understanding instruction pipelines, registers, memory addressing, and communication protocols.
- **Digital Electronics and CPU Design:** Assisting in building the clock module, ALU, register systems, control system, and program counter using fundamental logic gates.

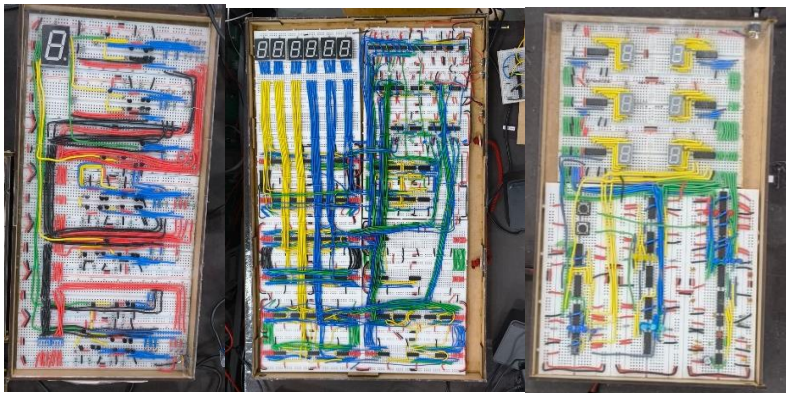
- **Development of Educational Modules:** Creating simple yet powerful electronic demonstrations to learn digital logic, binary arithmetic, and computer architecture for students and layman.
- **ICT and Curriculum Integration:** Applying theoretical knowledge from my ICT coursework at PDEU to real-world electronics, circuit debugging, and system-level thinking.
- **Outreach and Demonstration Support:** Assisting in explaining these models to visitors, educators, and stakeholders during workshops, exhibitions, and CCL lab visits.

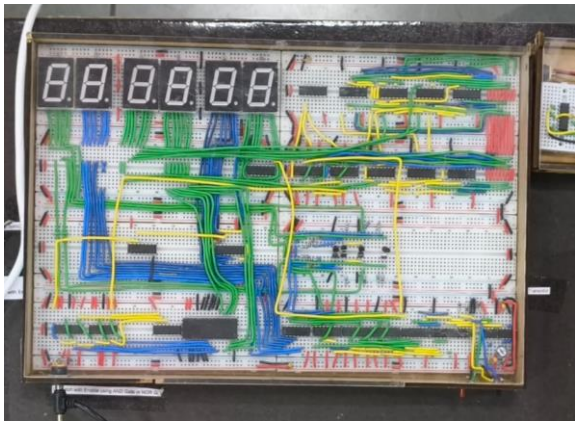
These experiences have enabled me to work at the intersection of creativity and technical precision, reflecting CCL's philosophy—**learning by doing, exploring, and building from first principles**.

3. Impact Work Done at CCL

Fig: Project Madhava

Project Madhava is an initiative aimed at building a complete understanding of computing - from the fundamentals of logic gates made using simple components like paper clips and transistors, to fully functional digital calculators and an 8-bit CPU. It bridges the gap between theoretical electronics and tangible experimentation, enabling learners to *see* and *build* computation from first principles. The project embodies CCL's philosophy of learning by doing, curiosity, and creative exploration.





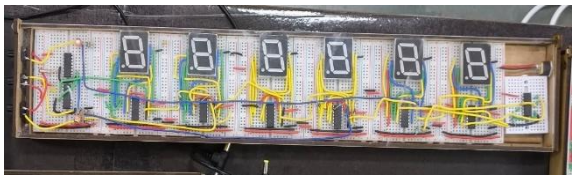
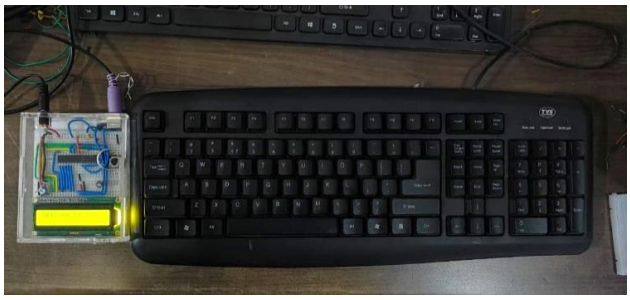
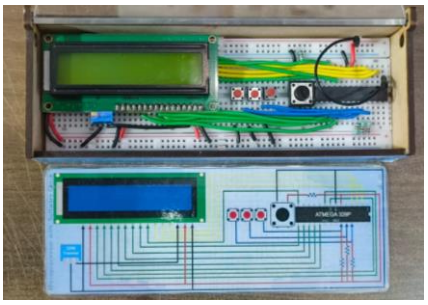


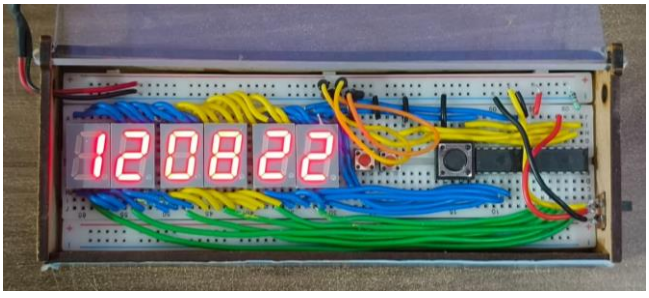
Fig: Clocks

(i) TTL 7 Segment Decoder (ii) Clock using logic gates decoder and 555 timer (iii) Clock using JK Flip Flop as counter and 555 as timer (iv) Clock where each display is decoding using different logic - transist (v) Compact Digital Clock using 4026 ic

The earliest phase of **Project Madhava** began with our effort to build simple yet transparent digital systems that could reveal how computation emerges from basic logic. As a team, we started by creating a series of clocks—first using a hand-designed seven-segment decoder built purely from TTL logic and K-map simplifications, then versions made using JK flip-flops, and later integrated designs using the 4026 counter-decoder IC. These foundational modules demonstrated multiple ways of achieving the same behavior through different electronic philosophies, setting the tone for the project's larger goal of reconstructing computing step by step from its most elemental building blocks.







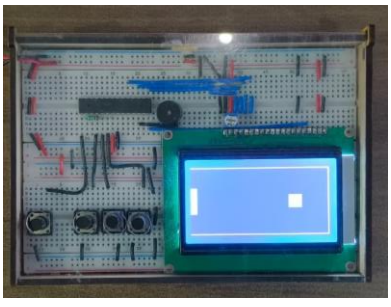


Fig: ATmega328

(i) PS2 Keyboard and LCD Protocol programmed using AVR Assembly on ATmega328 (ii) Clock programmed with AVR Assembly on ATmega328 with internal timer (iii) Clock with external crystal timer on ATmega328 (iv) Tetris Game on ATmega328 with Graphical LCD

A major portion of my time at CCL was devoted to developing a series of embedded systems on the ATmega328, aimed at understanding computation through low-level control - assembly. The first was a fully functional keyboard-to-LCD interface, where keystrokes were read over SPI and displayed with support for special keys like escape, enter, backspace, arrows, and shift. I then built two clock systems—one adjustable through user buttons, and another using interrupts, an external crystal, and a multiplexed seven-segment display. The final module was an interactive Tetris implementation on a graphical LCD, built by carefully working through the underlying display communication and rendering logic. These projects became a central pillar of my contributions to Project Madhava.

Fig: P4 and P10 Displays

(i) Keyboard to PS10 display using ATmega328 (ii) Tetris Game on P4 Display using esp32

I also worked with **P4 and P10 LED matrix displays**, where we built a system to type text from the keyboard onto the P10 module and create Tetris Game on the P4 display. While doing this, I explored and understood their low-level communication and timing in assembly, adding an important visual component to our Project Madhava tools.

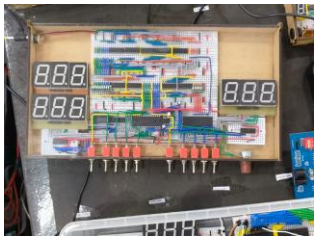


Fig: Calculator

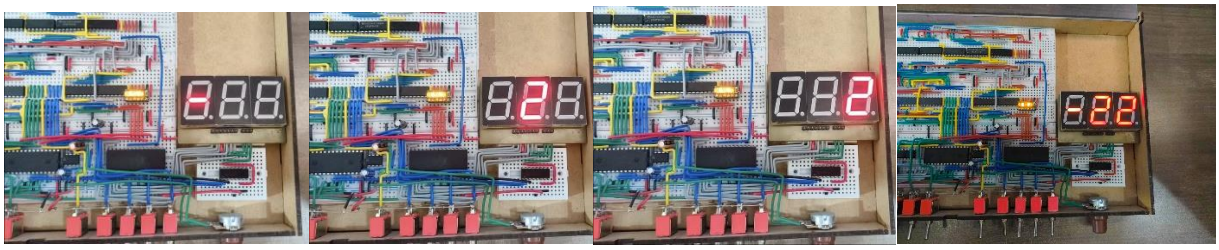


Fig: Multiplexing Screens

We also built a simple **digital calculator** that performs $a + b$ and $a - b$ using standard adder–subtractor logic, and interestingly, by extending the circuit we enabled it to compute $-a - b$ as well. Alongside this, I worked on a **multiplexed display setup** where each digit is shown sequentially—first "–", then "2", then "2"—and when driven with a higher clock frequency, the human eye perceives it as the stable output "–22." These modules served as intuitive demonstrations of arithmetic logic and display multiplexing principles within Project Madhava.

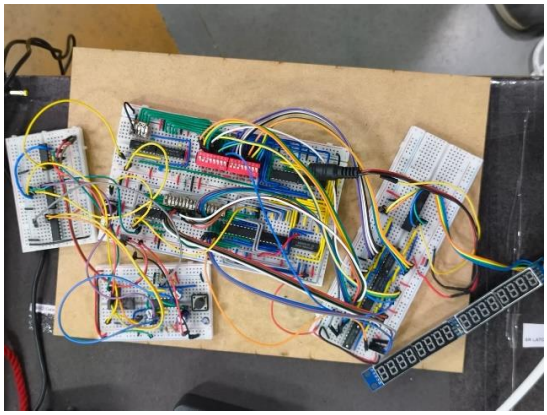


Fig: Multiplier

Fig: Ternary Game

Also worked on a sequential multiplier circuit capable of computing the product of two 8-bit numbers using repeated addition. The system advances through eight internal states - adding, shifting, and accumulating partial results - and therefore must be clocked exactly eight times to produce the final output. To facilitate this, we built a precise eight-pulse manual clock, where each button press advances the computation by one step, allowing learners to observe the multiplication algorithm unfold in real time. Alongside this, we created a small ternary game that introduces non-binary number systems and demonstrates the logic behind binary search through an engaging, hands-on activity.

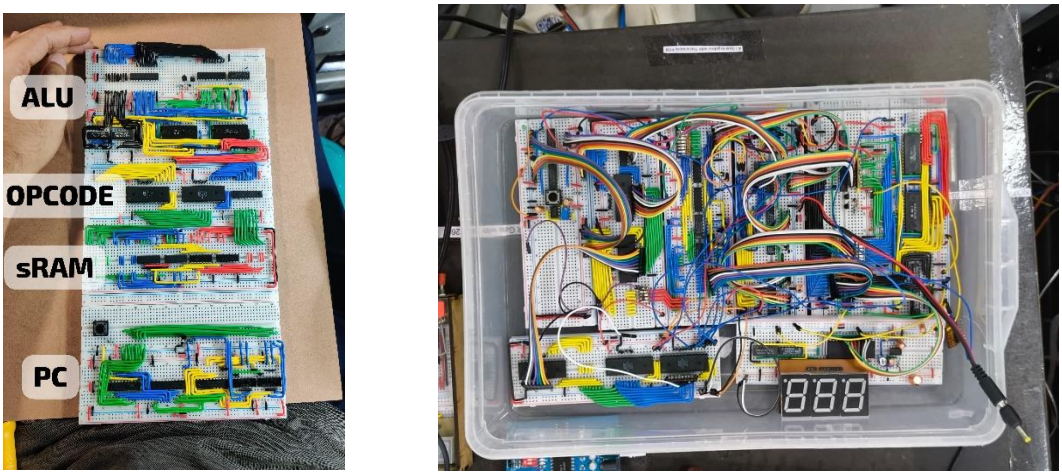


Fig: The 8 Bit Processor

(i) Elements of 8 Bit Processor (ii) Assembled 8 bit Processor

Finally, we constructed an **8-bit processor on a breadboard**, comprising an ALU, opcode and instruction decoder, address register, SRAM interface, and a program counter. Although the physical footprint appears compact, this is because we used **EEPROM-based lookup architectures** to implement several logical subsystems, allowing the overall design to remain faithful to the underlying instruction-level behavior while significantly reducing circuit complexity. This processor marks a major milestone in Project Madhava, bringing together computation, memory, control flow, and architecture on a fully observable, first-principles hardware platform.

Fig: 6-foot Tetris

We are also working on a fun project - large 6-foot Tetris installation using cascaded P10 LED displays, turning the classic game into an engaging, room-sized interactive exhibit.

4. Outreach and its Potential Impact

Our outreach activities became an important part of the internship, giving us the space to share Project Madhava with people who deeply shape India's scientific and educational landscape. Across visits and exhibitions—whether during the **Akhil Bhartiya Shiksha Samagam**, **ESTIC**, **Semicon**, or during special lab interactions—we had the opportunity to walk dignitaries through our demonstrations, explain the ideas behind them, and receive thoughtful questions and feedback. Leaders such as **Hon. Shri Ashwini Vaishnaw**, **Hon. Shri Dharmendra Pradhan**, **Hon. Shri Sridhar Vembu**, **Hon. Dr. S. Somnath**, **Prof. M.S. Ananth**, **Prof. Sundar Manoharan**, **Prof. Manjul Bhargava**, and **Dr. Narayan Konwar** spent time understanding the work, which was both motivating and affirming for our team. Their engagement highlighted how hands-on, first-principles STEM learning connects not just with students and teachers, but also with policymakers and scientists working at the highest levels of the country.

Fig: Hon. Shri Ashwini Vaishnaw, Minister of Electronics & Information Technology, Information & Broadcasting, and Railways

Fig: Dr. S. Somnath, former ISRO Chairman at AGM, IIT Delhi

Fig: Hon. Shri Dharmendra Pradhan, Minister of Education at ABSS, Bharat Mandapam

Fig: Hon. Shri Sridhar Vembu, CEO of Zoho Corporation at AGM, IIT Delhi

Fig: Annual General Meeting of all IIT directors at IIT Delhi

Fig: M. S. Ananth, former Director of IIT Madras visit to CCL

Fig: Dr. Sundar Manoharan, Director general of PDEU, Dr. Anirbid Sircar, Director of SOT, PDEU, Hon. Shri Narottam Sahoo, Sr. Scientist, Gujarat Science City and Dr. Bhawani Singh Desai, Dean RnD, PDEU visit to CCL

Fig: Cretus The Robotics Club, PDEU students visit at CCL

Fig: Madhava Project Proposal to MeitY

Fig: Prof. Manjul Bhargava at Akhil Bhartiya Siksha Samagam

Fig: 5th National conference of Chief Secretaries

Fig: Narayan Konwar, Secretary of Higher Education, Assam

Fig: IEEE UFFC-S, Special Topics School visit to CCL

Fig: AMC Gujarat All Principals' Meet at IIT Gandhinagar

Fig: 16th All Kerala CBSE Principals' Conference and Training

Fig: Semicon India Educational talk and exhibition

5. Learning Outcome

My internship at the Center for Creative Learning provided a comprehensive blend of technical, pedagogical, and experiential learning. Working closely on Project Madhava strengthened my understanding of **digital electronics, microcontroller architecture, and low-level system design** far beyond textbook exposure. Implementing modules in assembly deepened my grasp of instruction sets, addressing modes, timing constraints, communication protocols, and the internal functioning of processors—all of which closely align with the theoretical foundations covered in my ICT coursework at PDEU.

This experience also enhanced my ability to transition from conceptual circuit diagrams to **real hardware implementations**, reinforcing skills in debugging, signal tracing, timing analysis, and interfacing with external peripherals. I learned the importance of designing systems that are not only functional but also intuitive and educational for learners from diverse backgrounds, which sharpened my ability to explain technical ideas clearly and visually.

Beyond technical growth, the internship cultivated significant professional skills. Regularly demonstrating projects to educators, students, researchers, and national leaders helped build my confidence in communication and presentation. Collaborating within a multidisciplinary team taught me the value of iterative design, documentation, and creative problem solving. Overall, the internship strengthened both my engineering competence and my understanding of how technology and education can work together to make concepts accessible and impactful.

6. Conclusion

My time at the Center for Creative Learning has been transformative, shaping both my technical capabilities and my perspective on engineering education. Contributing to Project Madhava allowed me to work at the intersection of **embedded systems, digital logic, computer architecture, and experiential learning**, translating ICT concepts into tangible, demonstrable hardware. The opportunity to develop modules from first principles, interact with leading figures in science and policy, and participate in national exhibitions provided a level of exposure and responsibility that has deeply influenced my academic and professional aspirations.

This internship reinforced a fundamental insight: that understanding grows strongest when built from the ground up—through exploration, making, and sharing. The experiences, skills, and mentorship I received at CCL will continue to guide my learning journey and future contributions in embedded systems, computing, and STEM education. I remain grateful for the opportunity to work under the guidance of Prof. Manish Jain and to be part of a team committed to reimagining how India learns science and technology.

7. Outlook

Looking ahead, the work undertaken during this internship lays a strong foundation for continued collaboration between myself, CCL, and the larger vision of **Project Madhava**. The modular architecture we have developed—ranging from basic logic demonstrators to the 8-bit processor—opens multiple avenues for refinement, documentation, and large-scale dissemination. I hope to contribute further by expanding the library of demonstrable computing modules, improving system robustness, and creating structured learning pathways that integrate these tools into ITI, diploma, and undergraduate curricula.

From a technical standpoint, I aim to deepen my work in **embedded systems, FPGA-based design, and low-level computing**, building on the principles internalized at CCL. Integrating these domains with Project Madhava can lead to advanced models of computation that preserve first-principles clarity while enabling richer demonstrations. Simultaneously, I look forward to contributing to outreach efforts, helping translate complex ideas into accessible experiences for students, educators, and policymakers.

For CCL, the continued development of Madhava represents a significant opportunity to influence how foundational electronics and computing are taught across India. With growing national focus on semiconductor capability, indigenous design, and hands-on STEM education, projects like Madhava can play an important role in shaping early technical exposure. I hope to remain connected with CCL in this ongoing journey—through future collaborations, research, or extended project engagement—contributing to a shared goal of empowering learners to understand, build, and imagine technology from the ground up.

I hereby declare that the work presented in this Interim Internship Report titled *"Interim Report Internship (July - November 2025) at the Center for Creative Learning, IIT Gandhinagar"* is the result of my own efforts and learning during the internship period.

Signature of Student:

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Date: 13/11/2025