

The project involves the design and development of a cost-effective, 3-axis CNC machine tailored for precision PCB (Printed Circuit Board) production, targeting both professionals and hobbyists. This CNC machine, which emphasizes remote operability and real-time monitoring, features a robust aluminum structure and incorporates key hardware components like NEMA 23 stepper motors and ball screws. An Arduino Uno, paired with the GRBL library, controls the stepper motors, while a Raspberry Pi hosts a custom G-code sender, enabling remote access, control, and real-time video streaming. This unique combination provides affordability without compromising on precision, aligning with high-end commercial CNC options.

Key Components and Methodology

The CNC machine includes an array of components, such as:

- **Stepper Motors** (NEMA 23), **DC Motors**, **IR sensors** for safety, a **GSM module** for alerts, and a **touchscreen** for control.
- **Raspberry Pi**: Acts as the bridge between hardware and user interface, enabling remote monitoring and G-code processing.
- **GRBL**: An open-source software for parsing G-code, ensuring accuracy in operations.

Features and Design

The machine offers:

1. **Remote Control** via Raspberry Pi, allowing users to operate it from anywhere.
2. **Real-time Monitoring** with live camera streaming.
3. **Enhanced Safety** through IR sensors, limit switches, and an emergency stop button.
4. **Automatic Leveling** to optimize PCB placement for precision.

Results and Testing

Extensive tests were conducted, especially on the "PIC Basic Circuit," to demonstrate the machine's capabilities. The CNC machine showed impeccable precision in PCB production, saving time and reducing errors associated with manual production. Students and professionals found the machine effective in creating complex circuits with high reliability.

Challenges and Solutions

Key challenges included integrating the Raspberry Pi and Arduino systems, remote access configuration, and ensuring operational safety. These were addressed by employing a custom G-code sender and a server with wide accessibility. Safety measures, such as limit switches and high-quality motor selections, also enhanced reliability.

Conclusion and Recommendations

The CNC machine provides a viable solution for cost-effective PCB production with features that match commercial-grade equipment. Future enhancements could include expanded working area, advanced sensor feedback, and integration with PCB design tools. This project has opened pathways for affordable precision manufacturing, suitable for educational and small-scale industrial applications.