

Electric-Pneumatic Transfer Module for Countersink Operation

S. R. Pandit¹; Sudarshan Pangam²; Harshada Gaikwad³

^{1,2,3}Department of Instrumentation and Control Engineering, KBT College of Engineering, Nashik

Publication Date: 2026/06/01

Abstract: The Electric Pneumatic System for Countersink Module is designed to automate the countersinking process used in manufacturing industries. Countersinking is a machining operation that creates a conical hole for screw heads to fit flush with the surface. Traditional manual or semi-automatic systems are time-consuming and less accurate. This paper presents an automated solution using electric control and pneumatic actuation to improve precision, speed, and safety. The system integrates sensors, PLC control, pneumatic cylinders, and motor-driven tools to perform consistent countersinking operations. The proposed system ensures uniform depth control, reduced human intervention, increased productivity, and enhanced operational safety. The system was tested under different working conditions and showed reliable performance.

Keywords: Electric Pneumatic System for Countersink Module Includes Key Elements Such as Electric Motor, Pneumatic Cylinder, PLC Control, Solenoid Valve, Compressed Air Supply, Proximity Sensor, Tool Rotation, Linear Motion, Automatic Operation, Precision Machining, Workpiece Detection, Forward and Return Stroke, High Speed, Accuracy, and Industrial Automation.

How to Cite: S. R. Pandit; Sudarshan Pangam; Harshada Gaikwad (2026) Electric-Pneumatic Transfer Module for Countersink Operation. *International Journal of Innovative Science and Research Technology*, 11(5), 2616-2620.

<https://doi.org/10.38124/ijisrt/26may1307>

I. INTRODUCTION

Countersinking is a critical secondary machining process used to create a conical recess for flat-head fasteners. In high-volume production, manual handling and standalone countersink machines often lead to variability in quality, longer cycle times, and safety concerns. Automation using transfer modules addresses these challenges by ensuring controlled motion, precise positioning, and synchronized operation. Electric-pneumatic systems are widely adopted in industrial automation due to their balance of precision (electric drives) and power-to-cost efficiency (pneumatics). This research focuses on the development of a compact electric-pneumatic transfer module specifically designed to load, position, countersink, and unload workpieces with minimal human intervention.

II. LITERATURE REVIEW

Automated loading and machining systems are increasingly essential due to the demand for high efficiency. Manual methods are usually slow and result in low efficiency. The lack of specialized automated machinery is a primary cause for high labor costs. Automation provides accurate and controlled movement, reducing raw material wastage and ensuring uniform flow in downstream processes. Advanced systems also incorporate energy-efficient components to maximize cost-effectiveness.

III. METHODOLOGY

The development process starts with requirement analysis, where the functional and safety needs are defined, including torque and pressure requirements. The conceptual design phase involves creating a CAD-modeled structure that includes a tool handling system and a loading mechanism. In the component selection stage, high-precision motors, proximity sensors, and PLC units are chosen to ensure accurate and reliable operation. Prototype development is then carried out by building a working model to validate the system's precision and speed. The programming phase involves developing PLC-based automation logic using Ladder Logic to control the system. Finally, safety testing is conducted by implementing fail-safe mechanisms and emergency shutdown systems to ensure safe operation.

➤ Key Features:

- PLC Control: Automates countersinking with precise valve and magnet control.
- Pneumatic Actuation: Drives cylinders smoothly using compressed air.
- Electromagnetic Holding: Holds and releases the workpiece automatically.
- Automated Operation: Reduces human effort and errors.
- High Accuracy: Maintains consistent depth and quality.
- Efficient & Safe: Speeds up work with better safety.
- Manufacturing Friendly: Fits easily into production lines.

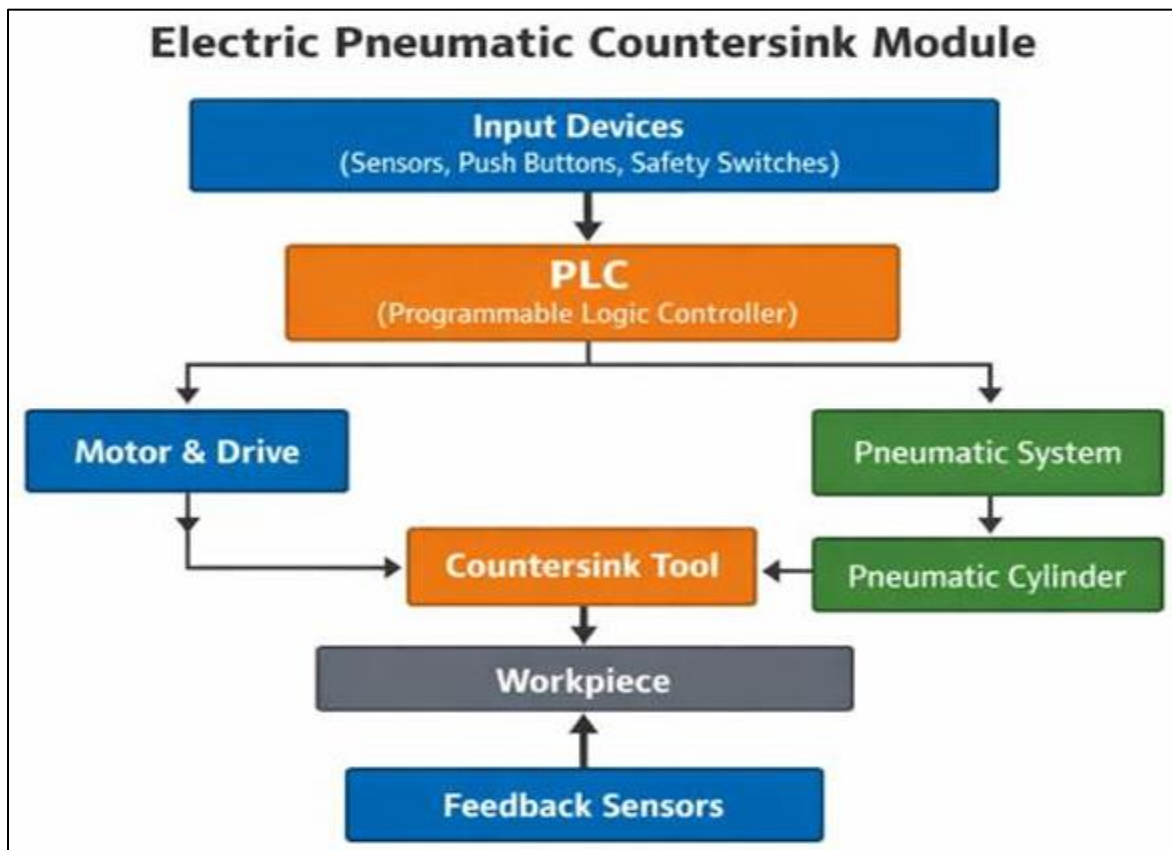


Fig 1 System Architecture

Electric pneumatic countersink module shows how the system works in a simple flow. Input devices like sensors and push buttons send signals to the PLC, which acts as the main controller. The PLC processes these signals and controls both the electrical system (motor and drive) and the pneumatic system (solenoid valve and cylinder). The motor rotates the

countersink tool, while the pneumatic cylinder moves it forward and backward. The tool performs the countersinking operation on the workpiece. Feedback sensors continuously send signals back to the PLC to ensure accurate and safe operation.

IV. HARDWARE IMPLEMENTATION



Fig 2 Solenoid Valve

➤ *Solenoid Valve*

The black components are solenoid valves, which control the flow of compressed air. The blue tubes are air pipes that carry compressed air from the supply to different actuators (cylinders). Each valve opens or closes based on electrical signals (usually from a PLC), allowing air to move

the cylinders forward or backward.

At the bottom, the terminal wiring connects these valves to the control system. This setup enables precise and automatic control of multiple pneumatic movements in the machine.



Fig 3 PLC (Mitsubishi FX5U)

➤ *PLC (Mitsubishi FX5U)*

This PLC is the main control unit of the system, responsible for controlling machines like your electric pneumatic countersink module. It receives input signals from sensors and sends output signals to devices such as motors, solenoid valves, and relays.

firmly holds the cutting tool for smooth and accurate rotation. The rotating tool removes material from the workpiece to create a conical hole.

The workpiece is tightly fixed using a fixture to avoid movement. A pneumatic cylinder moves the tool up and down for cutting operation. The base plate supports the system and keeps everything properly aligned.



Fig 4 Drilling Tool

➤ *Drilling Tool*

The top cylindrical part contains the motor that rotates the countersink tool at high speed. The tool holder below it

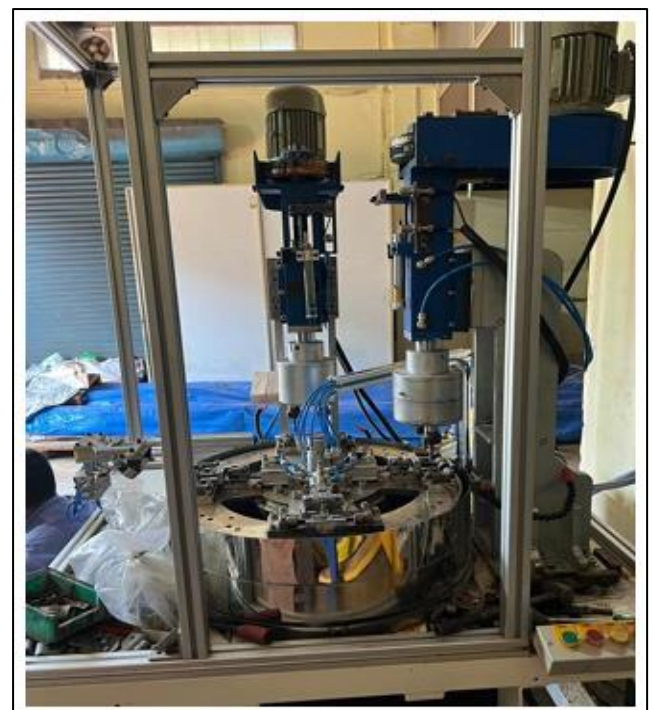


Fig 5 System Architecture

➤ *System Architecture*

At the top, there are electric motors mounted vertically. These motors rotate the countersink tools at high speed for cutting operations.

Below each motor, you can see the spindle assembly and tool holder, which holds the countersink tool and ensures precise rotation.

In the middle section, there are pneumatic cylinders (with blue air pipes). These cylinders provide vertical motion, moving the rotating tools downward and upward during the operation.

At the bottom, there is a circular indexing table (rotary table). Multiple fixtures are mounted on this table to hold several workpieces at different stations.

The entire setup is enclosed in an Aluminium frame with safety guarding, and on the side, you can see control buttons (start/stop/emergency) for operation.



Fig 6 Proximity Sensor

➤ *Proximity Sensor*

In your system, an inductive proximity sensor is used to detect metal workpieces. When the metal comes near the sensor, it sends a signal to the PLC. This helps the machine know whether a part is present before starting the operation



Fig 7 Pneumatic Cylinder

➤ *Pneumatic Cylinder*

Pneumatic Cylinder converts compressed air into linear mechanical motion to operate the shutters. its double-acting configuration provides efficient bidirectional motion for opening and closing. durable and cost-effective for high-speed industrial operations. provides reliable and precise motion control for the shutter mechanism.

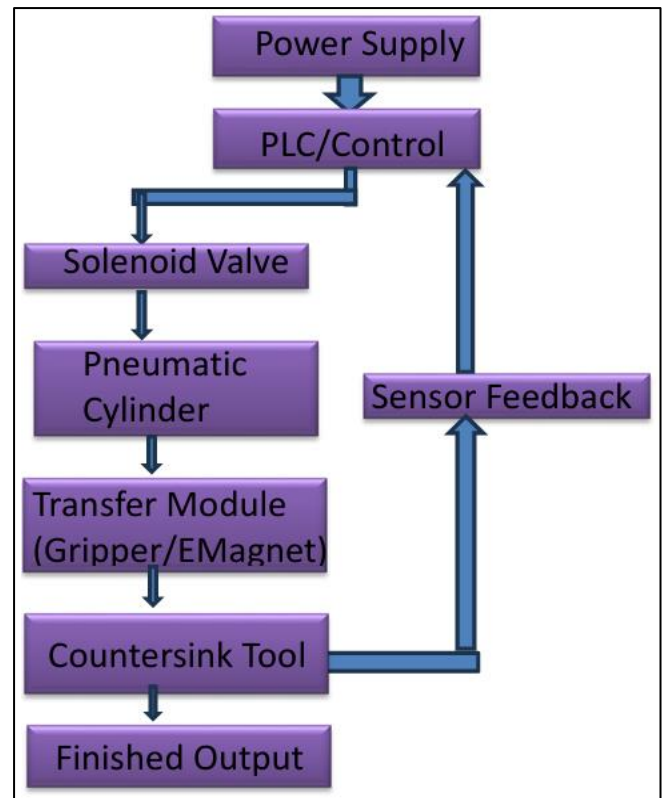


Fig 8 System Flow Chart

➤ *Process Flow Diagram of System*

The entire system works like a synchronized dance between electricity and air pressure, all managed by a digital brain called the PLC. It starts when a sensor "sees" a workpiece in the station, which tells the PLC to trigger a pneumatic clamp that grips the part firmly so it doesn't move. Once the part is secure, the PLC signals the electric motor to start spinning the countersink tool at a specific speed controlled by the VFD. After the motor reaches full speed, a second pneumatic cylinder slowly pushes the spinning tool downward into the material. This descent continues until a depth sensor or limit switch is hit, at which point the PLC immediately reverses the air flow to pull the tool back up safely. Finally, the motor stops spinning and the clamp opens, leaving a perfectly finished hole and resetting the machine for the next part.

V. RESULT

The electric pneumatic countersink system demonstrated highly efficient and reliable performance in industrial machining applications. By integrating an electric motor for high-speed rotation with a pneumatic actuator for controlled linear motion, the system achieved precise and consistent countersinking results. The countersink tool

operated smoothly, producing clean and accurate chamfered holes with minimal surface defects. The incorporation of proximity sensors ensured accurate position sensing and improved automation capability, while the PLC-based control system provided effective synchronization between electrical and pneumatic operations. This reduced human intervention, minimized errors, and significantly increased production rate.

Furthermore, the system maintained stable performance due to consistent air pressure, which ensured uniform tool feed and cutting depth throughout the process. Safety features such as emergency stop mechanisms, overload protection, and proper insulation enhanced operator safety and system reliability. The module also exhibited high repeatability, making it suitable for mass production environments where precision is critical. Maintenance requirements were relatively low due to the robust design and efficient component selection. Overall, the electric pneumatic countersink system proved to be a cost-effective, durable, and high-performance solution, meeting both productivity and quality requirements in modern industrial settings.

VI. CONCLUSION

The electric pneumatic countersink system can be concluded as a highly efficient, precise, and dependable solution for modern industrial machining processes. The successful integration of electrical and pneumatic components enables accurate control of speed, position, and force, resulting in superior countersinking quality. The system ensures smooth and consistent operation, producing uniform chamfered holes with minimal error and excellent surface finish. Automation through PLC and the use of proximity sensors enhances operational accuracy, reduces human effort, and increases overall productivity.

Moreover, the system offers high repeatability and reliability, making it suitable for continuous and mass production environments. The stable pneumatic pressure ensures consistent tool feed and depth, while the electric drive provides high-speed rotation for effective material removal. Safety features such as emergency stop, overload protection, and proper system insulation contribute to safe working conditions. The design also allows easy maintenance and long service life, reducing downtime and operational costs. In conclusion, the electric pneumatic countersink system is a cost-effective, robust, and technologically advanced solution that meets the demands of precision engineering and automated manufacturing industries.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor, Mr. S. R. Pandit, for giving me the valuable opportunity to work on the project titled “Electric Pneumatic System For Counter Sink Module Using PLC for Automotive Industry.” This project has provided me with a great learning experience and helped me gain knowledge about various new concepts and technologies. I am truly thankful for his guidance, support, and encouragement throughout the completion of this project.

REFERENCES

- [1]. S. R. Majumdar 2017 *Pneumatic Systems: Principles and Maintenance*, Tata McGraw-Hill Education, New Delhi.
- [2]. Frank D. Petruzella 2016 *Programmable Logic Controllers*, McGraw-Hill Education, New York.
- [3]. Anthony Esposito 2019 *Fluid Power with Applications*, Pearson Education, London.
- [4]. Mikell P. Groover 2020 *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson Education, United States.
- [5]. W. Bolton 2018 *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson Education, UK.