

# Filling Machine Panel Retrofit into Arduino Nano-Based Digital System at CV Sarana Engineering

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**Abstract—** The control panel on the filling machine is an important component in the industrial automation system that functions to regulate the work sensors, actuators, and time-based control devices. This research begins with the emergence of ideas or needs to develop a system or solve a problem, which is then followed by problem identification and literature study to strengthen the theoretical basis. This study aims to redesign the filling machine control panel using a modular approach based on the Arduino Nano microcontroller. By replacing analog components with digital ones such as relay channels, LCDs, and modular PCBs, a cost efficiency analysis was carried out between the old and new systems. Testing was carried out by evaluating the response time, stability, and actuator coordination of the control panel, as well as conducting an economic analysis that included cost reduction and Return on Investment (ROI) calculations. These indicators were compared between the new and old panels to assess improvements in both technical performance and economic efficiency. The results showed that the new panel improved response speed, stability, and actuator coordination, while achieving cost savings of up to 80% compared to the conventional panel. The Return on Investment (ROI) analysis indicated an ROI of 405%, which demonstrates a significant economic advantage as the initial investment can be recovered multiple times over. This result highlights that the redesigned system is not only technically superior but also cost-effective and flexible, making it highly suitable for small to medium-scale industries. This system is also more modular, easy to program, and supports digital interface integration, making it a feasible and sustainable automation solution.

**Keywords—** Machine Filling, Automation, Arduino Nano, Return of Investment

## I. INTRODUCTION

In the modern industrial era marked by increasing the need for efficiency and production speed, automation is a very crucial aspect, including in the filling process. Filling machines are an important part of production in various industrial sectors, such as food and beverage, pharmaceuticals, and cosmetics. According to research,

automation in filling machines can increase production efficiency by up to 35% compared to manual systems. However, to support this automation system, a control panel that is reliable and flexible in operation is needed. Unfortunately, most small industries still rely on conventional systems based on electromechanical relays and analog timers that have proven to be less efficient in terms of space, cost, and scalability [1].

This problem also occurs in real life at CV Sarana Engineering, a company engaged in the assembly and supply of filling machines for small to medium industries. In initial observations, the control panel used still relies on conventional systems with separate analog components such as relays, timers, and mechanical counters. The findings of this study show that analog component-based control systems require larger physical space and complex wiring, which lead to higher production costs and longer assembly times. In addition, such systems are difficult to modify, making them less effective in meeting dynamic customer demands or handling breakdown conditions in the field [2], [3].

To overcome these limitations, it is necessary to redesign the control panel system with a more modern and efficient approach. Microcontrollers such as the Arduino Nano are a potential solution thanks to their small size, programming flexibility, and affordable price. Previous studies have shown that Arduino is capable of replacing various functions of analog components, such as timers and counters, in liquid mixing systems, while providing precise and stable results [4]. This approach not only simplifies the circuit, but also significantly reduces the space requirements and cost of components, making it suitable for use in small-medium industries.

In addition, the Arduino-based control system also allows integration with user interfaces such as LCDs and digital sensors, which support the concept of modularity and continuous development. His research developed an Arduino-based automatic liquid filling system and found that the system can work in real-time with high accuracy

and fast response. However, as highlighted by, most previous research has focused on technical aspects without examining the economic impact comprehensively, such as production cost efficiency, assembly time savings, and potential return on investment (ROI)[5], [6].

Based on these gaps, this research comes with a more comprehensive approach, covering technical and economic aspects in the redesign of the control panel of the filling machine using Arduino Nano, digital relays, LCDs, and other modular components. The goal is to evaluate the cost efficiency, ease of installation, and advantages of modularity of microcontroller-based systems, which have not been discussed simultaneously in one study. Research by states that modular control systems not only speed up the production process, but also facilitate the maintenance and expansion of the system in the future. Therefore, the design of this panel is expected to be a feasible, cost-effective, and flexible automation solution for small-medium industries such as CV Sarana Engineering [7].

II. METHODS

The methodology of this research is visualized in the form of a flowchart to clarify the stages of the workflow that are carried out systematically. The flowchart depicts the sequence of activities from problem identification to evaluation of the system that has been designed. The following is a flow diagram of the filling machine with an electro-pneumatic system

A. Flowchart

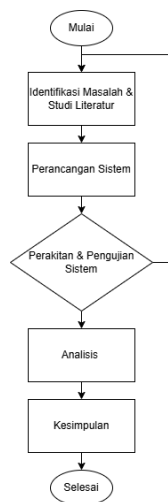


Fig. 1. Flowchart Diagram

This research begins with the initiation of ideas and identification of needs to develop a system or solve a problem, which is then followed by problem identification and literature study to strengthen the theoretical basis. After understanding the issues at hand, the researcher designed the system by defining the components, workflows, and an overall system architecture and workflow. The process proceeds to the assembly and testing stages of the system to ensure it functions as expected, where modifications are made if discrepancies are found during testing. Furthermore, an analysis of

system performance is carried out based on test data to assess the achievement of objectives and identify deficiencies. The study closes with conclusions that summarize the results, achievements, and suggestions for further development [8].

B. Working principle of machine Filling

The filling machine operates using a piston mechanism driven by a pneumatic system to fill liquid into bottles in a semi-automatic manner. The process begins when the liquid is stored in the hopper tank, then flows into a volumetric cylinder through a three-way valve. When the piston is pulled back by the pneumatic cylinder, the liquid from the hopper enters the volumetric cylinder. Once the cylinder is filled, the valve changes position to connect the cylinder with the nozzle. The piston then moves forward, pushing the liquid out through the nozzle into the bottle placed underneath.

Despite its benefits, the system also presents limitations. Components such as the pneumatic cylinder and seals require regular maintenance to avoid leakage or performance degradation. In addition, the machine depends on stable air pressure and needs periodic calibration to maintain accuracy. For further development, this filling machine could be enhanced with full automation by integrating sensors, flow meters, and microcontroller. This would allow for better real-time monitoring, safety improvements, and energy efficiency. Moreover, a comparison with alternative filling methods, such as gravity-based or peristaltic pump systems, shows that the piston-pneumatic design is especially advantageous for medium- to high-viscosity liquids, whereas other systems may perform better for very low-viscosity or foamy products.

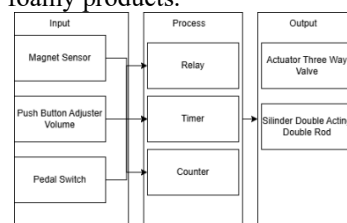


Fig. 2. Application's Block Diagram

Fig 2 shows a diagram block of an automatic pneumatic control system consisting of three main parts, namely input, process, and output. In the input section, there are three devices, namely a magnetic sensor to detect the position of the cylinder and stop the process when the desired step is reached, a push button volume adjuster that functions to adjust the filling volume from 10 ml to 1000 ml, and a pedal switch as an initial trigger that is operated by the foot. These three inputs send signals to the process section consisting of relays, timers, and counters. The relay serves as an electromechanical switch to stream the control signal to the pneumatic system, the timer sets the working duration so that each cycle lasts within the right time span, while the counter calculates the number of working cycles thus allowing production monitoring. Furthermore, the signal from the process part is passed to the output part that drives the pneumatic cylinder to perform the forward and backward movement of the piston

as the main mechanism of filling the liquid into the bottle. This part of the output can also be equipped with indicators in the form of lights or buzzers to provide feedback on the status of the system, such as cycle completion or fault detection. The integration of these three parts results in a semi-automatic control sequence that guarantees volume accuracy, repeatability consistency, and operating efficiency in pneumatic-based filling systems.

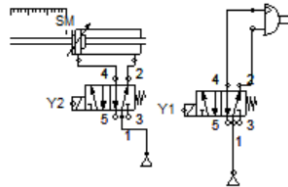


Fig. 3. Filling Machine Filling Output Pneumatic

The results of this processing are passed to the output part as shown in Fig 3, namely the actuator three-way valve and the double acting double rod cylinder that executes mechanical movements according to the system's commands as shown in Fig 4. Where position 1 is when the filling machine is in standby position and position 2 is the filling process. In figure 5 is an electro-pneumatic filling machine.

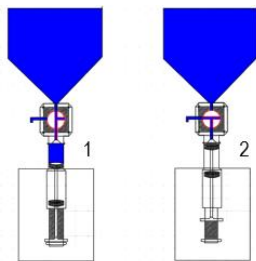


Fig. 4. Filling Machine Filling Process



Fig. 5. Machine Filling

### C. Previous Filling Machine Control

Previous Filling Machine Control was designed using a relay logic-based control system consisting of components such as relays, timers, counters, switches, and indicators. This system functions to automatically set the filling process based on a specific working order and time [9]. The entire series is packaged in a panel box that serves as a container to protect and tidy up the installation of components. Three selector switches are used to select the operating mode, such as manual, automatic, or off. In addition, two-time delay relays are used to set the time lag

between processes so that charging runs according to the specified duration. Control panel shown on fig 6



Fig. 6. Filling Machine Control Panel

### D. Retrofit Design Machine Filling

On Fig 7 shown retrofit design machine filling, a more compact control system is used using Arduino Nano as the main controller. Relays are used to control actuators in the form of three-way valves and double acting double rod pneumatic cylinders [10], [11], [12].

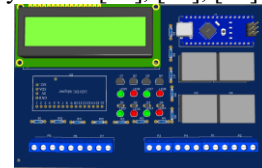


Fig. 7. Filling Machine Control Module Using Arduino Nano

### E. ROI (Return On Investment)

Return on Investment (ROI) is a measure used to evaluate the efficiency or profitability of an investment, by comparing the benefits of the return earned against the costs incurred. ROI is usually expressed in the form of a percentage. In the case of the comparison of old panels and new panels, ROI is used to measure how much profit or cost savings are obtained if we replace an old panel system that uses conventional components with new panels based on Arduino Nano microcontrollers. To find out the ROI value, see equation (1)

$$ROI = \left( \frac{\text{Benefit} - \text{Cost Investment}}{\text{Cost Investment}} \right) \times 100\% \quad (1)$$

Benefit refers to the total value of the savings or profits generated from an investment, while investment cost is the amount of funds spent on making the investment. The difference between the benefits and the cost of the investment is referred to as the net profit. The result of dividing the net profit by investment costs is then multiplied by 100% to get the ROI value in the form of a percentage [13], [14], [15].

## III. RESULT AND DISCUSSION

### A. Return of Investment analysis

To start the analysis, it is necessary to make a comparison between the old panel and the new panel to see the extent to which efficiency and cost savings can be achieved through the application of microcontroller-based technology. The old panels used a conventional approach with electromechanical components such as magnetic sensors, relays, TDR (time delay relay), and relay

counters. Legacy Panel systems relied on separate physical wiring and hardware circuits to perform functions. A multi-colored LED is used as an indicator, and control is done via push button as well as a switch selector. Components such as relays and TDRs are used to set up the control logic analogously, In terms of dimensions, the panel has a relatively large size, adapting to the number of physical components used

Table 1. Budget Plan Cost of Old Machine Filling

Item	Total Price
Panel box 40x30x15	Rp.279000
Sensor magnet	Rp.133000
LED panel (2x10k)	Rp.20000
Selektor switch (3x15k)	Rp.45000
TDR (2x150k)	Rp.300000
Relay + soket (5x62k)	Rp.310000
Relay counter	Rp.150000
Emergency	Rp.10000
Push button	Rp.10000
Total	Rp.1.257.000

On the new Panel Use controls with Arduino Nano modules, which provide high flexibility in logic settings and system controls. The use of LCD allows for a more interactive display of information. The system is designed to be more compact and digital, utilizing 4-channel relays and custom PCBs for component integration. The terminals are used for neater and more modular cable connections. The panel size is smaller and more efficient than the old panel, reflecting a more modern and space-saving design.

Table 1. Budget Plan Cost of New Machine Filling

Item	Total Price
Arduino Nano	Rp.48000
LCD	Rp.40000
Relay 4 channel	Rp.35000
PCB	Rp.20000
Terminal (7xRp.840)	Rp.5880
Panel box 30x25x12	Rp.100000
Total	Rp. 248.880

The Return on Investment (ROI) analysis between the old panel and the new panel shows a significant difference in costs. The old panel has a total cost of IDR 1,257,000, while the new panel only costs IDR 248,880. The cost difference of IDR 1,008,120 makes the new panel about 80% cheaper than the old panel. Assuming that the new panel is able to effectively replace the functions of the old panel as well as offer additional advantages such as automation and programming flexibility, the resulting ROI is around 405%. On the cost comparison obtained indicates that the new panel is not only more economical, but also provides added value in terms of efficiency and integration of automated systems

**B. Experiment Work Cycle of Old Filling Machines**

In the performance testing of the filling machine, the focus is directed toward analyzing the cylinder motion dynamics and the actuator activation time to evaluate the overall response speed and accuracy of the system. To obtain precise and reliable data, magnetic sensors are strategically installed along the cylinder trajectory at 0 mm, 20 mm, 40 mm, 60 mm, and 100 mm positions. The placement of these sensors enables detailed monitoring of

displacement over time, allowing the evaluation of how quickly the cylinder reaches each position and how closely the movement follows the intended control signal.

The system is tested using specific activation scenarios designed to simulate real working conditions. The semi-rotary actuator and cylinder are activated simultaneously at the 2nd second, followed by the termination of the semi-rotary actuator at the 4th second, while the cylinder system continues until the 7th second. This timing sequence replicates the duty cycle of the actual machine, ensuring that the test conditions closely represent practical operations.

From these scenarios, the relationship between control signals and mechanical responses can be analyzed. For instance, the time delay between the signal sent and the cylinder reaching a particular position can be measured, along with the response curve of displacement versus time. This allows for identifying potential issues such as overshoot, lag, or irregular stroke movement. Furthermore, the collected data provides insight into the system’s reliability, particularly in maintaining accuracy across multiple cycles under varying loads and air pressures.

Overall, the performance test not only validates the efficiency and repeatability of the pneumatic system but also highlights areas for improvement. To enhance the evaluation, it is recommended to include quantitative parameters such as the measured response time (in milliseconds), maximum error tolerance, and average cycle speed. Presenting the results in the form of graphs or tabulated data would strengthen the analysis and provide a clearer understanding of the system’s operational performance compared to standard industry benchmarks.

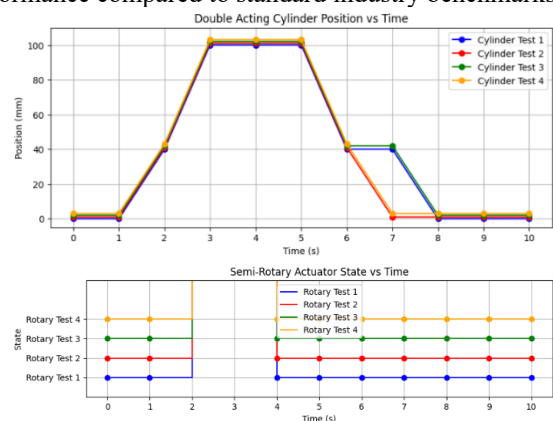


Fig. 8. Working Cycle Control Machine Filling Old

In the performance testing of the filling machine, an analysis of the dynamics of cylinder motion and actuator activation time was carried out to evaluate the overall response speed of the system. The magnetic sensors are strategically placed at 0 mm, 20 mm, 40 mm, 60 mm, and 100 mm positions along the cylindrical trajectory to obtain accurate data on position changes over time. In the performance of the filling machine, the engine activation time is set at the 2nd second, at which point the double acting cylinder and semi-rotary actuator must be activated at the same time. In the Cylinder Test 1, 2, 3, and 4 experiments, consistent movement was observed, i.e. the

position of the cylinder rose from 0 mm to 40 mm, and then reached the maximum position at 100 mm. This maximum position lasts up to 5s

At the time the system reaches the 4s time the semi-rotary actuator must be deactivated to prevent the overflow of liquid from the hopper to the filling area. Based on the measurement results, all semi-rotary actuators successfully turned off on time 4s, which shows that the control system is working accurately. However, in the double acting cylinder test, there was a difference in performance in Cylinder Test 1 and Test 3, especially in the phase of lowering back to the starting position. This difference is due to technical factors such as a delay in the pressure filling time from the compressor, so that the pressure supply to the valve is insufficient to push the cylinder back quickly and stably

### C. Experiment Work Cycle of New Filling Machines.

In the following filling machine tests, it is carried out to find out the reliability of the latest filling machine control, the time setting can be faster by combining the multitasking program on Arduino, namely Millis, so that the delay obtained on the machine is faster. To find out its performance, you can see fig 9

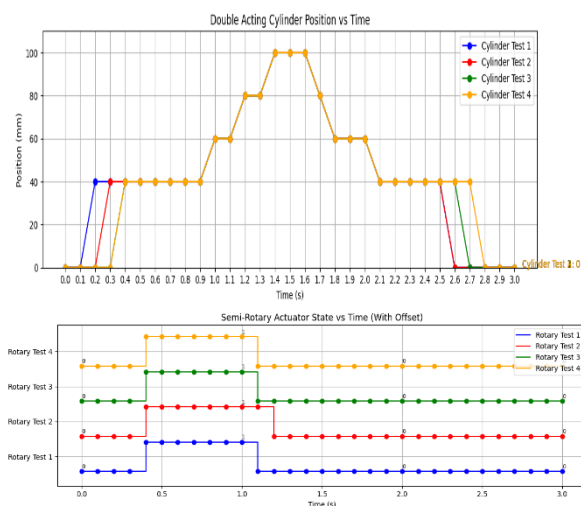


Fig. 9. Working Cycle Control Machine Filling New.

Based on fig 9, it can be observed that the system is capable of working quite quickly in a fraction of a second. The speed of the system is affected by the air supply from the compressor. To achieve maximum performance, the system must obtain adequate and stable air pressure. Without sufficient air supply, the performance of pneumatic components, especially cylinders and semi rotary actuators, will not be optimal. From the test data obtained, it can be seen that the activation of the cylinder occurs earlier compared to the semi-rotary. In detail, the activation time of the cylinder in the test showed that cylinder test 1 was active at 0.1 s, cylinder test 2 at 0.2 s, and cylinder test 3 and 4 at 0.3 s. The activation of the cylinder that precedes the semi-rotary indicates that the working order of the system has been in accordance with the working principle of the filling machine, where the cylinder must first complete

its mechanical task before the semi-rotary performs its rotational movement. Thus, the workflow of the mechanism can take place in a coordinated and effective manner. Although test 2 found that the semi-rotary off-time was slightly longer than other tests, it did not have a significant impact on the overall performance of the system. The delay is more caused by time fluctuations in the control of the microcontroller, especially in the time reading function using Millis ().

Millis functions on microcontrollers running multiple processes simultaneously often experience jitter or small inconsistencies in time intervals, leading to a shift in activation or shutdown time in multiple actuators. Although there are delays, it does not affect the stability and speed of the system's work so that it can still be maintained. Overall, the system has shown good performance and is in accordance with the designed working sequence. The activation of the cylinder that precedes the semi-rotary is an indicator that the system control logic has been precisely arranged. Although there is a slight time difference due to technical factors in the microcontroller, this problem is still within the tolerance limit and does not interfere with the main function of the filling machine. To maintain optimal system performance, the two main things that need to be considered are the stability of the air supply from the compressor and the accuracy of the control time from the microcontroller.

## IV. CONCLUSION

Based on the results of performance testing on the old and new versions of the filling machine control system, it can be concluded that the new design provides significant improvements both technically and economically. In the old system, the magnetic sensor successfully recorded the displacement of the cylinder along its trajectory (0 mm to 100 mm) with good accuracy, and the control logic correctly deactivated the semi-rotary actuator at the 4th second according to the predefined test scenario. However, a performance deviation was observed in the cylinder drop phase during Cylinder Test 1 and Test 3, which was caused by a delay in compressor pressure supply, resulting in slower response and cycle inconsistency.

In contrast, the new system, which adopts a multitasking method using the Millis () function on the microcontroller, shows a faster and more stable response. The cylinder was activated 0.1–0.3 seconds earlier than the semi-rotary actuator, which aligns with the intended mechanism sequence of the filling machine. This early activation indicates a more precise coordination between actuator signals and mechanical motion. Although a slight jitter from the Millis () function was observed in the downtime of the semi-rotary actuator, the deviation remains within acceptable tolerance and does not affect the system's main function. Overall, the new system achieves better response speed, time efficiency, and operational stability compared to the old version.

From an economic perspective, the improvement is even more pronounced. The old control panel required a total cost of IDR 1,257,000, while the new panel only cost IDR 248,880, resulting in a saving of IDR 1,008,120 (~80% cheaper). Based on these figures, the estimated Return on Investment (ROI) reaches 405%, proving that the new system is highly cost-efficient. Beyond cost savings, the new panel also provides added value through flexibility in programming, better automation capabilities, and easier integration with future system upgrades. In summary, the new control system not only demonstrates superior technical performance with faster actuator response, more reliable sequencing, and improved efficiency but also ensures significant cost reductions and better adaptability for industrial applications. These findings confirm that the upgraded system offers a strong balance between technical reliability and economic feasibility, making it a more sustainable solution for filling machine operations systems.

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