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Simulation Analysis of Fuzzy-PID Controller to Liquid Level System of Milk Pasteurization Tanks using LabVIEW

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ABSTRACT: Currently, As recently as the nineteenth century, humans risked serious illness or even death by drinking liquids—such as milk, juice, or even water—that were several days old. By contrast, today's beverages have a long shelf life thanks to the pasteurization process, named for the nineteenth century French scientist Louis Pasteur.Pasteurizing a liquid provides many benefits. Providing a longer shelf life when compared to unpasteurized milk. Elimination of volatile aroma compounds from certain foods.The paper describes about the liquid level control system which is commonly used in many process control applications. The output of the level process is non-linear and it is converted into the linear form by using Taylor Series method. The aim of the process is to keep the liquid level in the tank at the desired value. The conventional proportional-integral-derivative (PID) controller is simple, reliable and eliminates the steady state error. Fuzzy logic controllers are rule based systems which are logical model of the human behavior of the process. The fuzzy controller is combined with the PID controller and then applied to the tank level control system. This paper compares the transient response as well as error indices of PID, fuzzy, fuzzy- PID controllers. The responses of the fuzzy-PID controller are verified through simulation. From the simulation results, it is observed that fuzzy-PID controller gives the superior performance than the other controllers. The absolute error of fuzzy-PID controller is 56.6% less than PID controller and 55.6% less than the fuzzy controller. The Lab VIEW software is used to simulate the system. The simulated results validate the method implemented here.

KEYWORDS: PID control, Level Control,Milk Pasteurization, Packaging and Bottle filling, MyRIO, LabVIEW, Flow control.

I. INTRODUCTION

Joseph Mercola, DO, osteopathic physician and author, in an Apr. 16, 2016 article for Mercola.com titled "Raw Milk and Cheese Are Undergoing a Renaissance as Artisanal Foods Rise in Popularity," wrote: Pasteurizing milk destroys enzymes, diminishes vitamins, denatures fragile milk proteins, destroys vitamin B12 and vitamin B6, kills beneficial bacteria, and promotes the growth of pathogens.Meanwhile, raw milk contains:

- Healthy bacteria that are beneficial for your gastrointestinal tract
- More than 60 digestive enzymes, growth factors, and immunoglobulin (antibodies). These enzymes are destroyed during pasteurization, making pasteurized milk harder to digest
- Phosphatase, an enzyme that aids and assists in the absorption of calcium in your bones…

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Pasteurizing milk kills off all bacteria, including the health-giving lactobacilli. This allows milk to putrefy with bad bacteria over time, rather than sour or ferment from good lactobacilli. Pasteurization also destroys vitamins, especially C, B6 and B12, and denatures fragile milk proteins. Pasteurization is important because the bacteria naturally found in some foods can make you very sick. Eating unpasteurized foods can lead to fever, vomiting and diarrhoea. In some cases it can lead to conditions like kidney failure, miscarriage and even death. So, we created this project to maintain pasteurization process in a proper manner throughout using automation by using LabVIEW. This process design handles storage, heating, condensation and packaging of milk after all the process.

II. BLOCK DIAGRAM

The Figure 1 shows Block Diagram of the system,

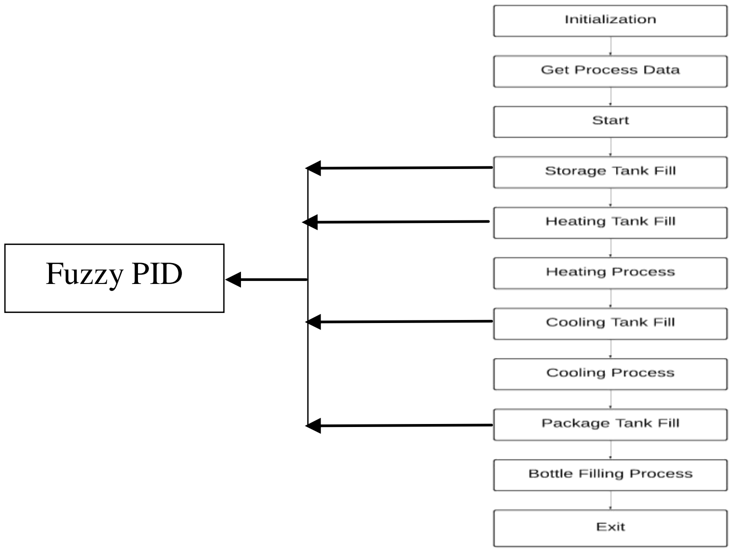

Fig .1 Block Diagram of the System

Figure 1. So, for the process of our system we designed with a structure of block diagram. Where it consider the steps we followed to complete the setup.

Initialization begins the process with process UI diagram as an user interface point of contact. Then Block 2 Get Process Data gets data to take over the process from the User interface and start the process by start block.

Start block receives process data & starts the process. Then Block 4 Storage Tank Fill, This process block consists of Valves and Storage tank, which gets turned on after start process and starts filling the tank. After Storage Tank Fill Block 5 Heating Tank Fill takes place and this block works on Heating and Temperature control setup to perform boiling of milk to get pasteurized. When the heating tank got filled then Block 6 Heating Process occurs and this block works on Heating and Temperature control setup to perform boiling of milk to get pasteurized. After the milk got heated to the boiling point then Block 7 Cooling Tank Fill starts to process, This block works on Valve control and Cooling tank filling process.When, the cooling tanks gets filled then the Block 8 Cooling Process comes into picture and This block works on Cooling and Temperature control setup to perform cooling of milk to the normal room temperature. After when the milk attains room temperature Block 9 Package Tank Fill and this block consists of valve from tank 3 and storage tank to store pasteurized milk. Then Block 10 Bottle Filling Process, This block works on valve control for bottle filling with conveyor belts to move the bottles and finally Block 11 Exit, This block exits the program simulation after execution. Every Tank is connected to Fuzzy PID Control to control over the tank's level.

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III.HARDWARE DESCRIPTION

1. myRIO:

myRIO is a portable device and students can easily use it for the design and control of robots and may other systems quite efficiently. It operates on the frequency 667 MHz.myRIO has dual core ARM cortex A9 programmable processor. It has a Xilinx Field Programmable Gate Array (FPGA). FPGA support in myRIO helps the students to design real life developing systems and to solve real problems quite faster as compared to the other micro controllers. Using FPGA support we can avoid the complicated syntax used in C language and in many other. We just have to create logic instead of writing the complicated code with the proper syntax. So, it has reduced the student's difficulties while designing complicated systems. It is student friendly device and is very easy to use. The processing speed of myRIO is quite higher than the standard micro controllers. So, it can be used t solve real life problems and it can be easily used in efficient systems which need a quick output response. It supports different languages e.g. C, C++ and graphical language (FPGA). The further detail about NI myRIO will be provided later in this article.

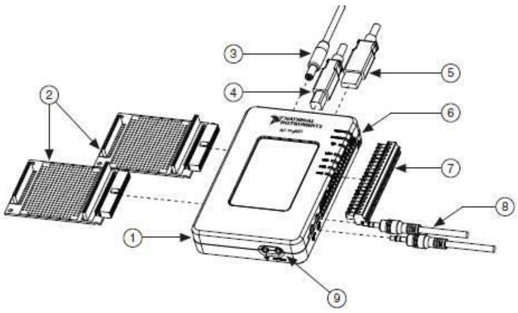

Fig.2 myRIO pin out Diagram

The NI myRIO-1900 has one UART receive input line and one UART transmit ouput line on each MXP connector. The UART lines are electrically identical to DIO lines 0 to 13 on the MXP connectors.

MyRio Control and Apparatus: -

1. NI myRIO-1900
2 .myRIO Expansion Port (MXP) Breakouts (One Included in Kit)
3. Power Input Cable
4. USB Device Cable
5. USB Host Cable (Not Included in Kit)
6. LEDs
7. Mini System Port (MSP) Screw-Terminal
8. Audio In/Out Cables (One Included in Kit)
9. Button 0

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IV. FLOWCHART

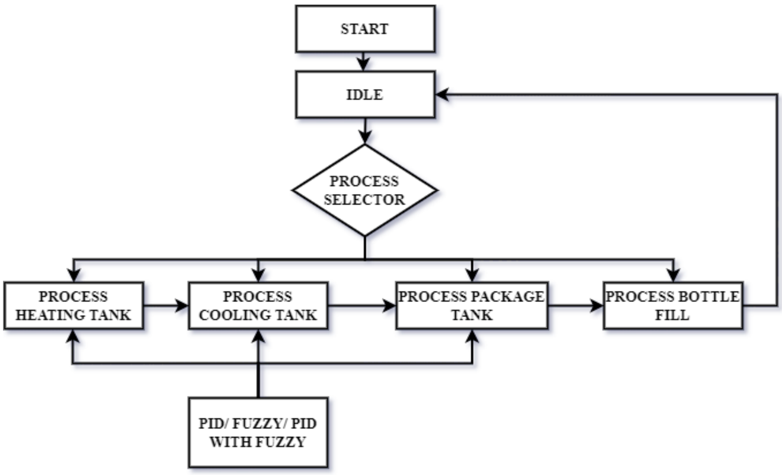

Fig.4.1 Flowchart part 1

V. SOFTWARE DESCRIPTION

1. LABVIEW:

LabVIEW (**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench) is a graphical programming environment which has become prevalent throughout research labs, academia, and industry. It is a powerful and versatile analysis and instrumentation software system for measurement and automation.It's graphical programming language called G programming is performed using a graphical block diagram that compiles into machine code and eliminates a lot of the syntactical details.LabVIEW offers more flexibility than standard laboratory instruments because it is software-based. Using LabVIEW, the user can originate exactly the type of virtual instrument needed and programmers can easily view and modify data or control inputs. The popularity of the National Instruments LabVIEW graphical dataflow software for beginners and experienced programmers in so many different engineering applications and industries can be attributed to the software’s intuitive graphical programming language used for automating measurement and control systems.

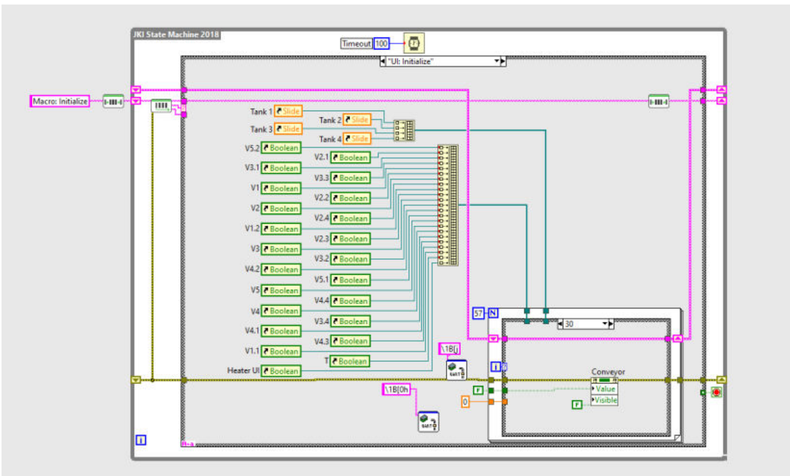

Fig.5.1UI initialize - Block Diagram

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Fig.6 LABVIEW Front Panel of Milk Pasteurization and Packaging with Controllers

VI. FORMULATION AND CONTROL DESIGN

The tank system [1-2] is shown in Fig. 1. In the figure, $q_{in}$is the input into the tank whereas h is the output level for thetank system.

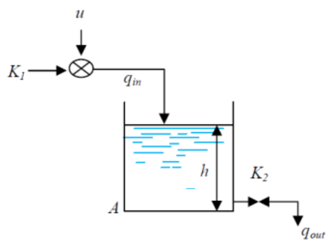

Fig.6.1SISO tank system.

For simulating the single input single output (SISO) tank system, its mathematical model [1] can be developed. The system is designed according to the mathematical model. For developing the mathematical model for SISO tank system, the density of liquid in the inlet, in the outlet and in the tank is assumed to be same and also the tank has straight vertical walls. The notations used in modelling the SISO tank system are

q_{in}= Inlet volumetric flow rate [cm3/sec]
q_{out}= Outlet volumetric flow rate [cm3/sec]
h = Height of liquid in the tank [cm]
ρ = Liquid density [gm/cm3]
A = Cross sectional area of the tank [cm2]

The mathematical model of the tank system is derived using the Mass balance equation as,

$$\frac{dm(t)}{dt} = \rho\, q_{in}(t) - \rho\, q_{out}(t) \quad (1)$$

$$\Rightarrow \frac{dh(t)}{dt} = \left(\frac{1}{A}\right) \times \left[K_1 u(t) - K_2 \sqrt{\rho\, g\, h(t)} \right] \quad (2)$$

The SISO tank system is designed according to the model in (2). The mathematical block diagram for the model in (2) is shown in the Fig. 2.

Equation (2) is nonlinear due to the presence of square root term. The equation can be linearized by using Taylor series which is

$$f(x) = f(x_0) + \left.\frac{df}{dx}\right|_{ss} \frac{(x-x_0)}{1!} + \left.\frac{d^2 f}{dx^2}\right|_{ss} \frac{(x-x_0)^2}{2!} + \ldots\ldots \quad (3)$$

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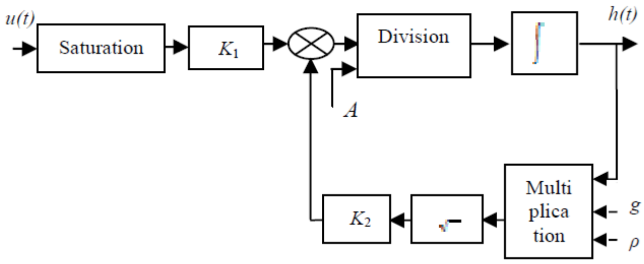

Fig 6.2 Block Diagram of Tank system

In the Taylor series, the higher order terms except the first two terms are neglected. The linearized version of (2) using Taylor series expansion described in (3) is,

$$A\frac{dH(t)}{dt} = Q_{in}(t) - C_2 H(t) \qquad (4)$$

Where $Q_{in}(t)$ and $H(t)$ are the deviation variables of $q_{in}(t)$ and $h(t)$ respectively.

If the process is initially at steady state, the inlet and outlet flow rates are equal. If the inlet volumetric flow rate is suddenly increased while the outlet volumetric flow rate remains constant, the liquid level in the tank will increase until the tank overflows. Similarly, if the outlet volumetric flow rate is increased while the inlet volumetric flow rate remains constant, the tank level will decrease until the tank is empty.The general form of PID controller is shown in Fig. 3. The error signal is the controller input and the actuator input is the controller output.

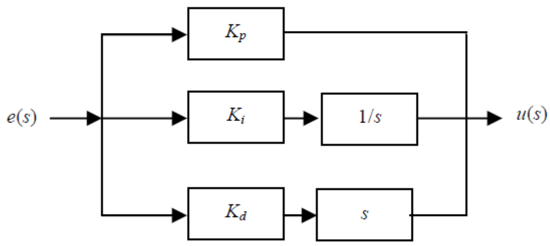

Fig.6.3. Block diagram of PID Controller

The governing equation of PID controller is,

$$m_{PID}(t) = K_p e(t) + K_p K_i \int e(t)dt + K_p K_d \frac{de(t)}{dt} \qquad (5)$$

The PID controller output in terms of Laplace transform can be written as,

$$M_{PID}(s) = K_p(1 + \frac{1}{T_i s} + T_d s) \qquad (6)$$

Due to the simplicity and excellent performance, PIDcontrollers are used in more than 95 % of closed-loop industrial processes for many applications. The PID controller can be tuned by using off-line control methods as well as online control methods. The control techniques of complex dynamic systems with nonlinear or time varying behavior are very difficult to determine the model of the process. Fuzzy controllers are able to summarize human knowledge of the system and integrate them to the laws of control. Fuzzy logic deals with linguistic and imprecise rules based on expert's knowledge [7]. Fuzzy parameters of the membership functions have been determined by using fuzzy system designer (FSD) in LabVIEW. In fuzzy algorithm,triangular-shaped built-in membership functions have been used. The fuzzy controller has two input variables. The error e(t) is the first input variable and the second input variable is the differential of e(t). The output (y) of fuzzy controller is the control signal of the actuator. The fuzzy linguistic variables with FSD tools described by five membership functions are shown in Fig. 4. The fuzzy logic controller (FLC) accepts the input variables, matches them up with the linguistic variables and determines the appropriate output corresponding to the input variables. The fuzzy rule base consists of a collection of fuzzy IF-THEN rules.

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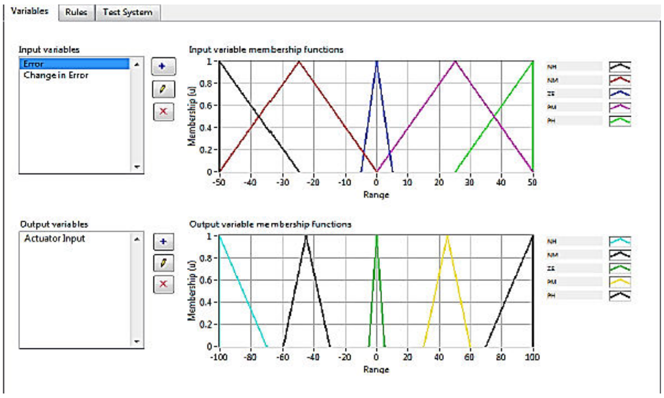

Fig. 6.4. Membership functions linguistic variables e, de/dt and y

Membership functions with linguistic values are describedas Negative High (NH), Negative Medium (NM), Zero (ZE),Positive High (PH), Positive Medium (PM), respectively.Linear type output membership functions have been used infuzzy rule base which has 25 fuzzy rules described in Table I.

e(t) / de/dt	NH	NM	ZE	PM	PH
NH	NH	NH	NH	NM	ZE
NM	NH	NM	NM	ZE	PM
ZE	NH	NM	ZE	PM	PH
PM	NM	ZE	PM	PM	PH
PH	ZE	PM	PH	PH	PH

Table 1 SET OF FUZZY RULES

The input/ output relationship of the system is shown bythe control surface in Fig. 5. It means that for every possiblevalue of the two inputs, there is a corresponding output basedon the rules. For example, if the error e and the changing rateof the error de/dt are given, the control output (actuator input)of the system can be obtained immediately. The input valuesof the error = 30.7487 and the change of rate of the error =25.4011, the output is about 57.52. Here, only six rules areneeded to calculate the output.

VII.PROCESS DESCRIPTION

Macro Initialize, To initialize the general data and the UI design. This creates the general look of User interface and provides an industrial front panel to make it crisp and clear.Data Initialize initializes user provided data and initializing all variables with its data types.Initialize Core Data to initialize the VI and the user interface as a combined process to provide a perfect result.Idle starts the process from set zero and receive user details to start the process and run through the setup with the provided data. This consists of the Production Quantity, Quantity per bottle, Max no of packets and User controlled Flow of different valvesError Handler performs error identification while a process is done and set back the system into set zero when it finds and error, and continues with a flow through the process.Restart – Condition confirms condition with the user while processing the process, when he/she/them wishes to turn the system run back due to lag in process. When Restart is pushed ON while the process is ON, it runs back to Data initialize, and initializes core data and initializes the UI. When Restart is OFF, it acts as Start and starts the process from the beginning.Start – Condition condition carries two solutions, where if it is yes, then enter the process selector and start the process. If the condition is no, then set back to idle.Emergency Stop – Condition receives the output YES of the Start Condition and performs two conditions. If YES, it performs UI initialize, Data initialize and Process Emergency stop. The Process emergency stop performs a quick stop in reaction as in the state where the conditions of all parameters gets stopped with set-zero. If NO, it performs Process selector and continues the start condition process flow.Select Process Multiple process flow, where it switches from one section to another as a relay by switching after each successful completion.

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Process Supply Tank Fill Valve 1 gets Turned ON and Supply tank gets filled.With all the process tanks we just added Level process control using PID control, Fuzzy Controller and Fuzzy-PID Control.

VIII.RESULT

The PID controller is tuned by Ziegler- Nichols tuning method, where the proportional gain Kp = 6, integral time Ti =0.035 and derivative time Td = 0.005. Fig. 8 represents theresponse of the PID controller which has overshoot of 5.07 %,settling time of 9.464 sec and rise time of 3.93 sec. Theresponse of fuzzy controller is shown in Fig. 8 .

Fig. 8. Response of PID controller, fuzzy controller and fuzzy-PID controller in Front Panel

Theovershoot, settling time, rise time in case of fuzzy controllerare 0.58 %, 13.324 sec and 4.93 sec respectively. Similarly, the response of fuzzy-PID controller is shown in Fig. 8 . It has overshoot of 0.12 %, settling time of 8.935 sec and rise time of 4.84 sec respectively. The combined transient response of PID, fuzzy and fuzzy- PID controller is presented. The fuzzy-PID controllergives better performance than the PID and fuzzy controller in terms of overshoot and settling time.

Type	% Overshoot	Settling Time(Sec)	Rise Time(Sec)
PID	5.07	9.464	3.93
Fuzzy	0.58	13.324	4.93
Fuzzy-PID	0.12	8.935	4.84

Table 2: Comparison of Transient Response of Different Controllers

The comparison of transient responses such as overshoot, settling time and rise time for the different controllers are shown in Table II. From the table, it is observed that the fuzzy-PID controller shows superior performance in terms of percentage overshoot and settling time in comparison to the conventional PID controller as well as fuzzy controller. The fuzzy-PID controller has 97.6 % less than PID controller and 79.3 % less than fuzzy controller in terms of overshoot. Similarly, the settling time is also 5.6 % and 32.9 % less than that of PID and fuzzy controller.The error indices such as integral absolute error (IAE),integral squared error (ISE), integral of time and absolute error (ITAE) and integral of time and squared error (ITSE) for PID controller, fuzzy controller and fuzzy-PID controller are compared in Table III. From the table, the absolute error of fuzzy-PID controller is 56.6 % less than PID controller and 55.6 % less than the fuzzy controller. The squared error is also 59.8 % less than that of PID and 49.5 % less than that of fuzzy controller in case of fuzzy-PID controller. Similarly, the ITA and ITSE of fuzzy-PID controller are 76.1 % and 87.1 % less than PID controller. Again, the ITAE and ITSE of combined controller is 76.3 % and 85 % less than fuzzy controller.

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IX.CONCLUSION

This paper presents the control of the level in a single tank using different controllers such as PID, fuzzy and the combination of PID and fuzzy controller. Numerical simulation indicates that the fuzzy-PID controller has more advantages than the conventional PID and fuzzy controller. The fuzzy-PID controller has less overshoot, good robustness and low settling time. Also, it has a strong ability to adapt to the changes of the system parameters and anti-disturbance performance. The controller efficiently tracks the set point. So, this controls the level of tank with different controllers.

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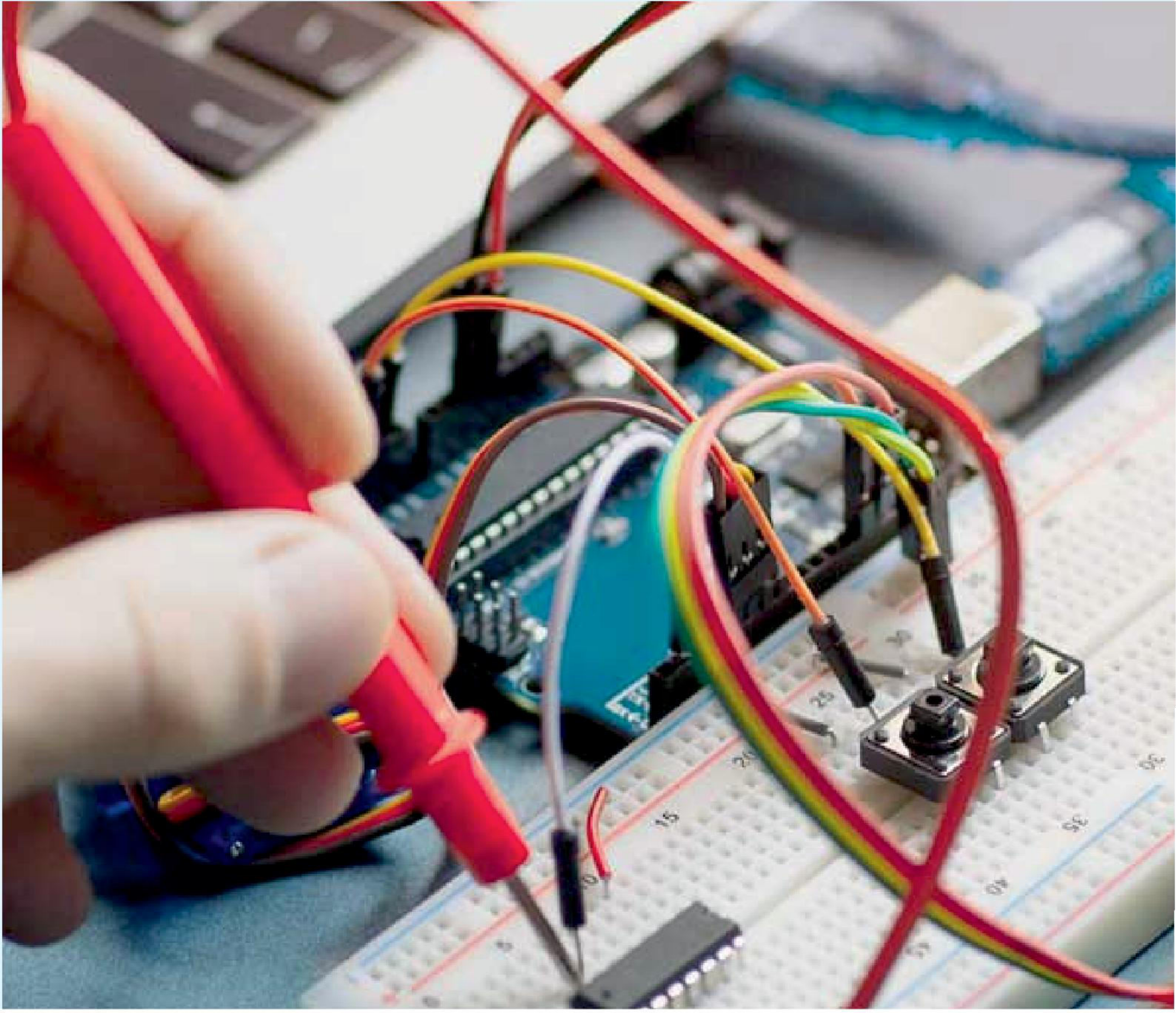

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