Development and Construction of Affordable Modular Electrical Training Aids for Automotive Electrical Training

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Abstract

This article examines the design and production of cost-effective automotive electrical training aids. These practical tools are intended for use as customized solutions in vocational education, facilitating hands-on learning experiences that allow students to efficiently acquire essential practical skills pertinent to the automotive industry.

The components outlined in this article can be utilized with several known electrical training systems, enhancing their affordability and functionality. This article will provide general descriptions of each component, including their specifications and dimensions. It will also outline options for the manufacturing process for ease of construction. This article aims to equip educators and trainers with the necessary tools to deliver effective and accessible automotive electrical training.

Introduction

Automotive electrical education is vital for the development of automotive students. With the continual advancement of automotive electrical systems, there is an increasing demand for affordable training aids that will effectively prepare students for careers in the automotive industry. By creating and producing electrical training aids within the automotive program, educators can supply students with course-specific components while minimizing the financial burden on the program's budget. The use of affordable training aids not only reduces costs but also enhances the quality of education, providing students with hands-on experiences that reinforce theoretical concepts and make automotive electrical training more accessible and effective.

Statement of Purpose

This article delves into the design and fabrication of affordable modular training aids specifically tailored for automotive electrical education. These innovative training tools can function independently or seamlessly integrate with other existing electrical training systems, offering educators the flexibility to adapt their teaching methods and enhance students' learning opportunities.

Statement of the Problem

Automotive electrical training aids tend to come with a high price tag, making them a significant investment for educational programs. This cost can pose a considerable challenge for smaller programs or those operating within tight budgets, limiting their ability to acquire essential training tools that enhance hands-on learning and experience in the field.

Discussion Question

What equipment and products can be utilized to design and produce cost-effective modular training aids for automotive electrical education?

Low-Cost Modular Electrical Training Aid Development

The development of low-cost modular electrical training aids begins with clearly defining the intended use of the training aids. This involves understanding the specific skills and knowledge learners need to acquire. Next, it is important to establish a budget that outlines the overall cost constraints to ensure affordability. Additionally, a thorough assessment of the availability of necessary components is essential. This includes evaluating local suppliers, considering bulk purchasing options, and identifying any potential alternatives or substitutes that may reduce costs without compromising quality. By carefully navigating these steps, effective and accessible training tools can be developed that enhance educational opportunities for all automotive electrical students and classes.

Components

Component Boards

Component boards can be manufactured using various techniques, each offering unique advantages. Key design features of these boards include standardized locations for standoffs (Figure 1), which provide stability and support during use, and socket connectors that facilitate reliable connections for the electronic components (Figure 2). Additionally, the boards incorporate specific mounting locations for various components (Figure 3), ensuring that each part is positioned correctly for optimal performance and ease of installation. By adhering to these design standards, faculty can enhance the compatibility and functionality of component boards across different applications.

In light of the requirements imposed by the standoff location, numerous manufacturers of electrical training systems have opted to implement a grid layout for their designs. Many of these systems feature a square grid measuring two inches by two inches, allowing clear and organized spacing between components. In contrast, some systems adopt a smaller grid size of one inch by one inch. This variation in grid dimensions can affect the level of detail and precision in electrical training exercises, catering to different educational needs and preferences.

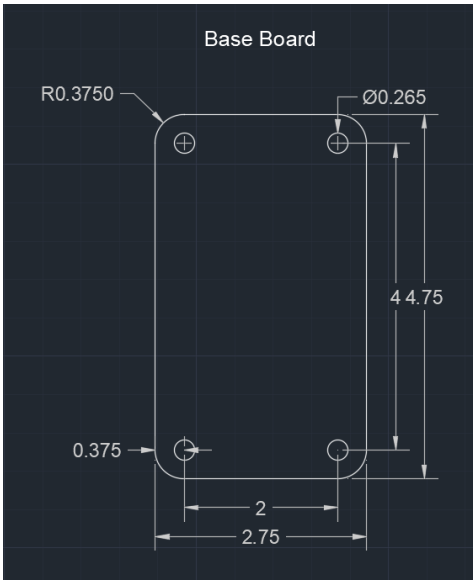

Figure 2 AutoCad Drawing of the Base Component board designed for a 2"x2" grid

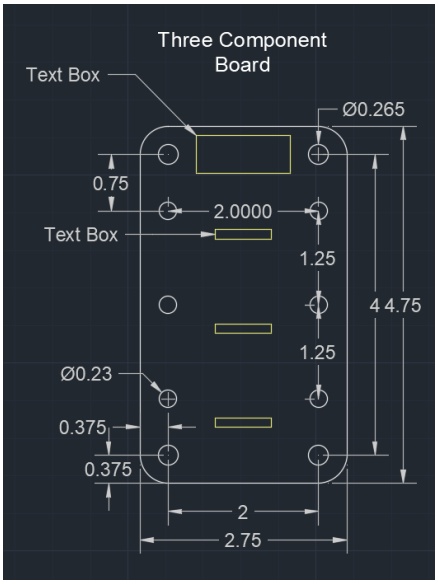

Figure 1 AutoCad Drawing for a Three Component Board with text boxes

Figure 3: Left: Laser Cut Dual Layer ABS Plastic Five-Component Board overlay with component labels. Center: Laser Cut Acrylic Five-Component Board. Right: Laser Cut Acrylic, Three-Component Board.

It is recommended to use a two-inch square grid for optimal compatibility with both systems. This specific grid size not only facilitates the use of affordable modular electrical training aids but also allows for the construction of customized boards in the workshop, utilizing standard pegboards as a foundation. This versatile approach ensures that pre-manufactured and handcrafted setups can be effectively integrated and utilized in training environments.

Standoffs

Standoffs offer a reliable and stable connection to secure component boards to pegboards or specially designed electrical training systems. This design enhances student engagement by ensuring that the boards are well-aligned and firmly attached, resulting in a more organized and effective training environment.

Banana plugs serve as standoffs in this setup (Figure 3). When selecting these standoffs, it is important to consider both cost and reliability. While some plastic standoffs are available at a low price, they may not withstand continuous use in a classroom setting. More durable options can be found at around $4 per standoff. It is advisable to use one standoff at each corner of the board, requiring a total of four standoffs per component board (Figure 4).

Figure 5 Left: Pomona Electronics 3265. Right: Flutesan B09P4N4LLB

Figure 4Left: 2"x2" Marker Lamp Bulb with Pomona Electronics Standoff. Right" 2"x4"Potentiometer board with Flutesan Standoff.

For those with budget constraints, lower-cost banana plugs can be purchased for under $0.50 each. This option would significantly reduce the overall expense from $16.00 for standoffs to less than $2.00.

The recommended standoffs are listed below, including their cost as of the date of publication. Prices may vary when buying in bulk. It should be noted that these are possible options. Construction and components can and should vary depending on the intended use, budget, and construction techniques. (prices referenced at the time of this writing)

Manufacturer	Part Number	Price per piece	Package Price	Vendor	Notes	Mounting hole Diameter
Pomona Electronics	3265	$3.50	Varies	Digikey	Lower Bulk Price	0.1575"
Pomona Electronics	3265	$3.39	Varies	Mouser	Lower Bulk Price	0.1575"
Keystone Electronics	6072	$3.49	Varies	Digikey	Lower Bulk Price	0.1575"
Flutesan	B09P4N4LLB	$0.35	60pcs $20.99	Amazon	Taller Board	.265"

Socket Connectors

Standard banana plugs are used to create electrical connections between various electronic components. These connectors feature a cylindrical metal post with a spring-loaded design that allows them to securely connect to corresponding socket connectors or jacks (Figure 6), ensuring a stable electrical path. One of the primary advantages of banana plugs is their ease of use; they enable quick and efficient connections and disconnections without requiring any additional tools.

These socket connectors are typically color-coded—often in red and black—to assist users in easily identifying positive and negative connections, reducing the likelihood of errors during installation or testing (Figure 7). Additional colors may be used to denote other connections for various inputs or outputs.

When connected to testing equipment such as a digital voltmeter (DVOM) or laboratory oscilloscopes, banana plugs allow automotive students to measure voltage, current, and waveforms. This capability is crucial for diagnosing circuit issues, validating circuit designs, and conducting thorough analyses of electrical systems. Overall, the use of banana plugs enhances the efficiency and effectiveness of electrical testing and experimentation in automotive educational settings.

Figure 6 XingYheng B091TH35NB

Figure 7 2"x4" Push Button Switch Board with Black and Red Banana Connectors

The recommended banana sockets are listed below, including their cost as of the date of publication. Prices may vary when buying in bulk. It should be noted that these are possible options. Construction and components can and should vary depending on the intended use, budget, and construction techniques.

Manufacturer	Part Number	Price per piece	Package Price	Vendor	Notes	Mounting hole Diameter
Walfront	B07BZZK4WN	$0.34	20pcs $7.01	Amazon	Multi color	0.230"
XINGYHENG	B091TH35NB	$0.27	40pcs $10.99	Amazon	Red and Black	0.230"
Keystone Electronics	6095	$1.89	Varies	Digikey	No Insulator	0.230"
Mueller	BU-00233-2	$1.94	Varies	Digikey	Red Insulation	0.250"
Mueller	BU-00233-0	$1.94	Varies	Digikey	Black Insulation	0.250"

Electrical Components

The electrical components utilized in the boards need to align closely with course objectives. Key components to focus on include a variety of switches that circuit control, circuit protection devices to safeguard against overloads and short circuits, and an array of loads that will effectively demonstrate the application and performance of the electrical system. Each of these elements plays an important role in achieving the desired outcomes of the course.

Switches

Switches are crucial in managing electrical loads, ensuring that systems operate safely and effectively. It is important to consider peak amperage when designing circuits, as many circuits should be designed to operate at or below 7.5 amps to prevent overheating and potential damage.

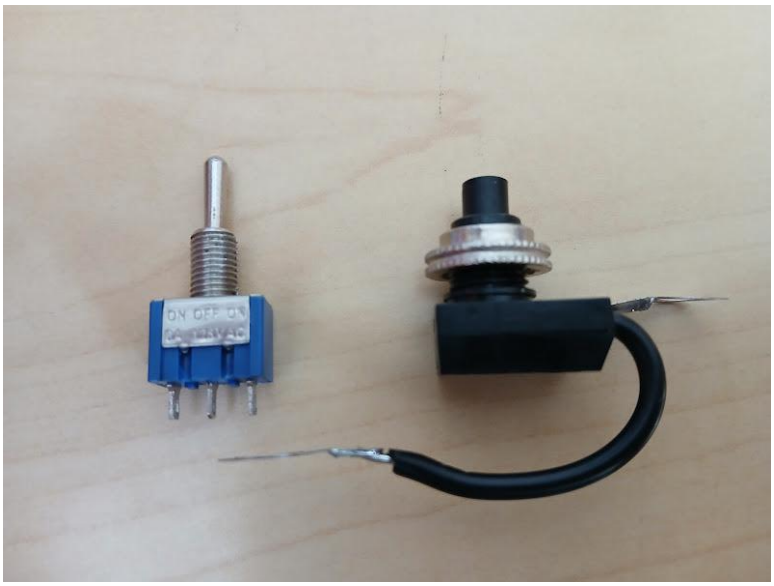

Figure 8 Examples of switches used in various component board

Toggle switches and momentary push-button switches are highly recommended for optimal performance and versatility. Toggle switches provide a reliable means of maintaining a steady connection, while momentary push-button switches offer a temporary connection (Figure 8). Incorporating these types of switches can enrich various learning outcomes, allowing for hands-on experiences that deepen understanding of electrical concepts and circuit design.

The available components will influence the selection of the switch type and its mounting configuration. Flutesan banana jack stand-offs allow for an elevated board design, which allows electrical connections beneath the board. This configuration eliminates the necessity for additional brackets to raise the switch above the component board. Consequently, this approach may enhance both the assembly efficiency and the design's overall aesthetic.

Circuit Protection

Circuit protection is an integral aspect of maintaining the safety and functionality of any electrical circuit. When dealing with multimeters, which are essential tools for measuring voltage, current, and resistance, one must pay careful attention to the protective components they are equipped with. Typically, most multimeters include a 10-amp fuse for the ammeter, which measures electrical current.

To protect the ammeter’s internal fuse, circuit protection below 10 amps are used to enhance safety and minimize the risk of circuit damage. This helps ensure that any unexpected surges or overloads do not compromise the ammeter or the circuit itself.

In a learning environment where students are utilizing these multimeters for experiments and practical applications, it is beneficial to use a 7.5-amp fuse. This lower-rated fuse protects the ammeter’s internal components, as it will blow at a lower amperage. By using this fuse, educators can help prevent the ammeter from experiencing potential damage, ensuring that students can obtain accurate readings while also fostering a greater understanding of safe electrical practices. Ultimately, selecting an appropriate fuse protects the equipment and contributes to a safer learning environment in electrical studies.

In addition to integrating a fuse into the circuit design, it is highly beneficial to construct a dedicated circuit protection board that features a circuit breaker with a rating of either 7.5 amps or 5 amps. Utilizing a circuit breaker not only enhances the overall safety of the electrical system

by allowing for quick disconnection in case of overloads or short circuits, but it also significantly reduces the regular expenses linked to replacing fuses, which can blow frequently as students are first learning electrical diagnostics.

Furthermore, the use of these circuit breakers is beneficial for developing simulated window circuits. These circuits can mimic real-world scenarios where electrical devices are connected to windows, allowing for practical testing and troubleshooting. With a circuit breaker in place, users can experience a more realistic environment that showcases how the system responds to faults, enhancing both training and operational effectiveness. Combining a circuit breaker and fuse creates a comprehensive protection strategy for various electrical applications.

Loads

Depending on the specific requirements of the circuit, the automotive course in question, and the allocated budget, a vast array of components can be incorporated into shop-built component boards (Figure 9). These components may include light bulbs, resistors that manage current flow, motors that convert electrical energy into mechanical energy, and various types of sensors that detect environmental changes, such as temperature or light intensity. Solid-state components like diodes, which allow current to flow in one direction only, thermistors that measure temperature changes, and photoresistors that alter resistance based on light exposure, can also be included.

Figure 9: Top: Relay, Bottom Left: 10KΩ Potentiometer, Bottom Middle: Marker Lamp Bulb, Bottom Right: Resistors, 100Ω, 1,000Ω, 10,000Ω

To maximize the effectiveness of these components in an educational context, each one will require a certain degree of customization. This may involve modifying the components to ensure they are easy to use, clearly identifiable, and tailored to meet the student's specific learning objectives. By doing so, the setup not only becomes more accessible for learners but also enhances their overall understanding of electrical engineering principles and practical applications.

Affordable Modular Electrical Training Aid Production

The production of affordable modular electrical training aids can be customized to accommodate the specific requirements and equipment variations of each automotive program. This flexibility ensures that the aids are not only cost-effective but also tailored to enhance the learning experience for students by aligning with the unique objectives and goals of each automotive program.

Manufacturing

Manufacturing component boards can present some challenges and may appear to be a time-consuming task. However, there are various methods for producing these boards that cater to the specific needs of each program, adhere to budgetary constraints, and accommodate available equipment.

Pegboards

One straightforward approach to constructing simple boards is to cut premade pegboards to the desired dimensions. These pegboards are widely available at local home improvement stores and are particularly useful due to their versatility. Typically, pegboards feature holes arranged in a one-inch grid pattern, which allows for easy customization, adaptability, and integration with pre-built systems.

The holes on these pegboards are usually pre-drilled in several standard sizes, including 1/8-inch, 3/16-inch, and 1/4-inch. For building component boards, choosing a pegboard with 1/8-inch holes is advisable. This size is beneficial because it allows for additional drilling to create holes that can accommodate a variety of components, such as standoffs and banana plugs, ensuring compatibility with various electronic parts.

When selecting pegboard, consider the specific requirements of the project at hand, including the type and size of components to be used. This careful planning will help ensure that the final product meets performance standards while remaining within budget and time constraints.

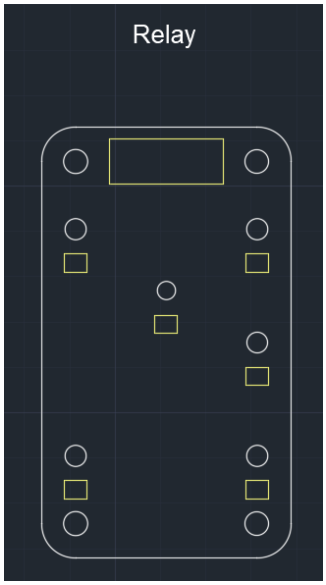

Figure 10: AutoCad Drawing for Relay Component Board

Computer-Aided Design

Component boards can be designed using computer-aided design (CAD) software. Programs like AutoCAD allow designers to precisely position various electronic components, including connectors such as banana jacks (Figures 10 and 11). This digital layout enhances both the understanding and functionality of the circuit. Once the design is finalized, it can be easily exported for production. The fabrication of these component boards may involve advanced methods, such as laser cutting for high precision or water jet cutting for heat-sensitive materials. Additionally, CNC machining provides versatility in shaping the boards, while 3D printing enables rapid prototyping and

innovative designs. Each of these techniques contributes to producing high-quality component boards that meet specific technical requirements.

Laser cutting, CNC machining, and 3D printing offer instructors valuable tools for labeling both boards and individual component boards. These technologies enable precise and customizable labels that enhance the identification and organization of components on the boards. This capability is especially beneficial in situations where a circuit board contains numerous components, such as resistors, which may vary in type and resistance values. By clearly labeling these components, instructors can facilitate a better understanding of the circuit design, making it easier for students to follow along and grasp key concepts related to electronics. Additionally, organized labeling helps prevent confusion during assembly and troubleshooting, ultimately contributing to a more effective learning experience.

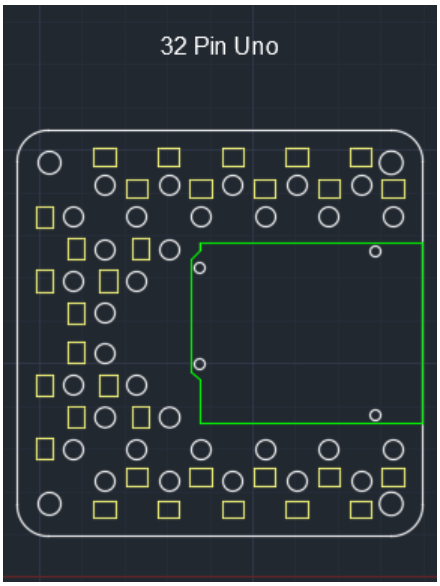

Figure 11 AutoCad Drawing for prototype Arduino Uno Component Board

In situations where an automotive program is unable to manufacture its own component boards, there are several online companies that offer fabrication services based on CAD drawings. One option is a company called, SendCutSend. These companies provide manufacturing capabilities across a diverse range of materials, including various plastics, wood, and metals. The components produced by these services are consistently characterized by high quality and accuracy. It should be noted that metal and metallic coated plastics are not appropriate materials for component boards.

Component Assembly

Once the component boards have been carefully fabricated using the previously described techniques, the next critical step is soldering. This process involves securely attaching various electronic components to the solder lugs of the banana jacks, ensuring a robust and reliable connection for optimal performance.

Custom jigs can be designed and manufactured to enhance the efficiency and precision of the soldering process. These jigs are invaluable for maintaining consistency in the positioning of components across multiple boards. Leveraging modern technology such as Computer-Aided Design (CAD) programs, CNC machines, lasers, and waterjets allows for the rapid and precise creation of these jigs. This advanced manufacturing capability significantly streamlines the component production process, resulting in high-quality assemblies that adhere to rigorous performance standards.

Recommendations

Recommendations for Practice

1. Automotive instructors and programs have the opportunity to create their own affordable modular electrical training aids, ensuring that students meet the required learning outcomes.
2. Developing shop-built training aids helps alleviate budgetary constraints faced by some programs, allowing for the acquisition of additional tools or equipment.
3. Instructors can design components tailored specifically to their program of study, aligning with their teaching methods.
4. Involving students in the development and construction of new components can enhance their skills in computer-aided design, fabrication, and soldering.

Recommendations for Further Development

1. The ongoing development of affordable modular electrical training aids ensures that the components remain relevant to the curriculum.
2. Additional elements, such as microcontrollers, can be incorporated into the system to control custom-built or manufactured components, facilitating instruction on computer-controlled systems.
3. The modular design of these components allows for the creation of larger displays that replicate the wiring of extensive systems, utilizing a large pegboard mounted on a wall or a stand.
4. The thoughtful design of the components, combined with a rapid production process, enables regular updates and reconfigurations, keeping them in line with the automotive industry and current trends.

Final Recommendations

Affordable modular electrical training aids can be developed by individual automotive programs tailored to address their specific educational objectives. These training aids can be constructed using readily available materials, such as plastic, wood, and basic electronic components, or through more sophisticated and precise manufacturing techniques that may incorporate advanced technologies.

Reducing the cost of these training aids allows automotive programs to reallocate their financial resources into other critical areas, such as curriculum development, student scholarships, or the acquisition of updated equipment. As a result, these programs can enhance the educational experience, ensuring that students receive the most relevant and hands-on training necessary to excel in the automotive field. By focusing on cost-effective solutions, automotive programs can improve their overall effectiveness and better prepare students for the evolving demands of the industry.