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Original article

Alarm driver board for microelectronic package legacy handlers

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ABSTRACT

This study was conducted to enhance the overall equipment efficiency by designing and developing an alarm driver board for tower lights and annunciators of the legacy handlers in microelectronic packaging. Audible and visible alarms are primarily used for monitoring the status of the legacy handler machines at a distance. These are important to manufacturing personnel, that when these devices fail, production can be compromised and translates into downtime. In this study, an alarm driver for tower light and annunciators have been developed to satisfy conditions for monitoring and control of status of the legacy handlers. A proto-shield printed circuit board was designed to handle input and output signals. It was made up of Optocouplers and Darlington transistors which also serves as a protection for both the handler and the microcontroller. An Arduino microcontroller unit was used to handle controls to satisfy the alarm conditions. An additional protection circuit was developed to avoid possible errors on the control system. Many trials were conducted supposing jams in the handlers. In result, the alarm driver board developed showed outstanding reliability. This setup is recommended for implementation to other handlers in the manufacturing of microelectronic packages

KEYWORDS: *alarm driver board, legacy handlers, Optocoupler, Darlington transistor*

1 INTRODUCTION

Alarms and Indicators The electrical testing of package integrated circuit (IC) ensures that the products are in standard electrical performance. The final setup in the production of IC packages is composed of testing equipment, handling equipment, and test hardware (Landicho et al., 2020; Tabacug et al., 2021). The legacy handlers of the final testing of the IC packages for several semiconductor companies are gravity-fed types which do not have standard tower light and buzzers for visual and audible alarms respectively (Ashe, 1994; S. Lee, Demidenkol, & Lee, 2007; Li, Choo, Chien, & San, 2004). Failed equipment tag (FET) issues related to the working condition of these alarms needs to be addressed. Therefore, a driver board for tower lights and buzzers must be developed. The tower lights provide information to operators while operating at the console. Operators rarely spend all of their time at the control panel. A high visibility tower light provides immediate machine status information across a greater area, especially when integral audible alarm buzzers are included when the operator is at a distance. Other personnel can also see the statues of the equipment for monitoring. Figure 1 presents a setup for tower lights in the production area.

The Legacy Handlers

In a test case, two handler models were analyzed, Handler A and B. Handler A is designed to handle and sort 300 mil dual-in-line packages (DIPs). It is a microprocessor-controlled handler which can produce 300 to 8000 units per hour (UPH). The handler B models are convertible handlers for different types of surface-mount devices (SMD) packages with varying pin configuration. Handler B is a tube-to-tube handler, where the tubes of untested devices are loaded into the handler and tubes of tested devices are removed. It is a tri-temp, extremely flexible test handler for different packages IC, power tab, and custom packages. These two handlers experience device jam such as bend device leads, improper carrier loading, wet devices, improper alignment or adjustments, foreign matters in the carrier tracks, and handler malfunction. When sensors fail in detecting these jams, production can be compromised. Immediate alarm must be triggered in order to avoid such instances.

This paper presents a method of developing an alarm driver board with adoptable tower light configuration. Through this setup, the overall equipment efficiency was improved when implemented in one of the semiconductor companies in the Philippines. The minor

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and major stoppages contributed to the handler equipment were immediately addressed by the operators using the developed alarm drivers.

Fig. 1. Tower light setup model (courtesy of ADPhils)

2 METHODOLOGY

Alarm Driver Board Design and Development The alarm driver board designed for both legacy handlers A and B, are made of devices such as microcontroller, signal conditioning devices, and other control devices mounted in a printed circuit board (PCB). The process flow diagram for the system is presented in figure 2. The circuit design was developed using the Eagle CAD software. It is simulated in Livewire and Proteus software. A proto-shield is assembled for the development of the PCB.

Fabrication

Different input signals are fed to handler A for process communication ranging from 0-5 V to 0- 24 V. These input signals from sensors have matching tower light and buzzer conditions as presented in Table 1. These signals should be matched to the Arduino compatible input signal.

For the input module, an Optocoupler is used to convert it into digital signals. The Optocoupler also isolates low power control circuit from high power signals (Cheng et al., 2014; Krishnaja & Acfc, 2018; Velasco et al., 2019) and vice-versa with Darlington transistors as amplifiers (Kitamura et al., 2007; Lin et al., 2013; Mojab & Mazumder, 2017; Pandey et al., 2015; Singh & Mehra, 2018). Specifically, a 4N35 Optocoupler with forward voltage of 1.3V (based on 10 mA) is used to match both 5Vdc and 24Vdc signals. A 2.2k ohms resistor is calculated for the input side of the Optocoupler. A slightly higher resistor value can also work, in this case, 3.3k ohms is used as presented in figure 3. To protect the input process module from reverse current, a diode was placed in series since the input threshold voltage could be above 5V. The collector pin 5 of the 4N35 is connected to the +5V of the Arduino. A pull-down resistor is connected to the output of 4N35 for protection.

For the output module with a 24V signal, a similar setup was used through a separate power source with the emitter pin 4 fed to the base of a TIP120 NPN Darlington transistor through a 1K ohms current limiting resistor. The collector of the TIP120 powers up either the tower light or the buzzer once 4N35 was triggered by the program. The schematic circuit has been created to put these modules in a PCB. This was illustrated in detail in Figure 5.

Table 1. Input/output Truth Table for Handler A.

No.	*Input signal from Handler A*	*Handler Status*	*Tower Light and Buzzer Condition*
1	Error (24 V) Start (5 V) Stop (5 V)	Idle	Steady RED only
2	Error (24 V) Start (5 V) Stop (0 V)	Stopped	Steady RED only
3	Error (24 V) Start (0 V) Stop (5 V)	Running	Steady GREEN only
4	Error (24 V) Start (0 V) Stop (0 V)	Indefinite	Steady RED only
5	Error (0 V) Start (5 V) Stop (5 V)	Jamming	Steady RED w/ Alarm ON
6	Error (0 V) Start (5 V) Stop (0 V)	Jamming, Stopped	Steady RED only
7	Error (0 V) Start (0 V) Stop (5 V)	Jamming	Steady RED w/ Alarm ON
8	Error (0 V) Start (0 V) Stop (0 V)	Indefinite	Steady RED only

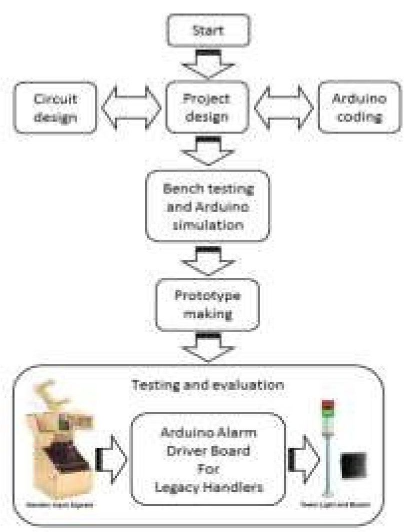

Fig. 2. Process Flow Diagram

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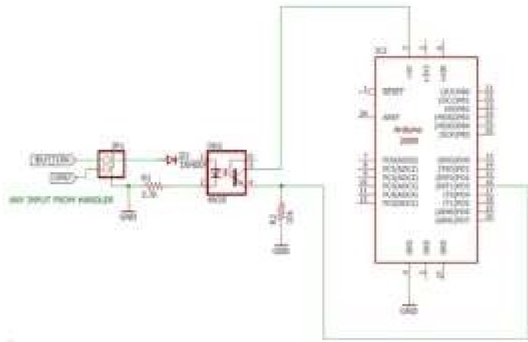

Fig. 3. Input Process Module

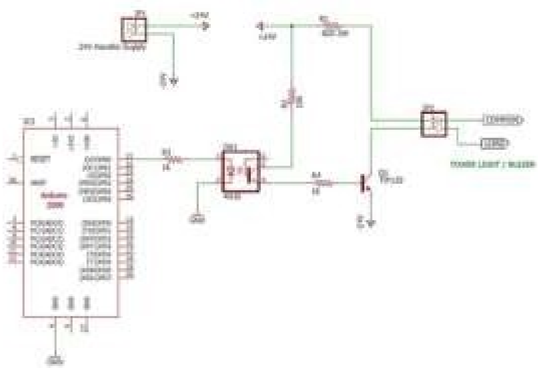

Fig. 4. Output Process Module

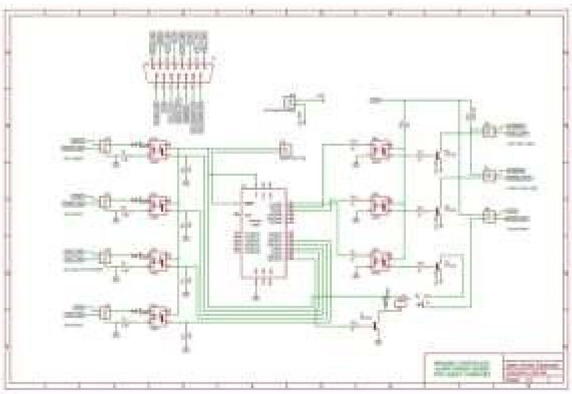

Fig. 5. Alarm Driver Board Schematic Diagram

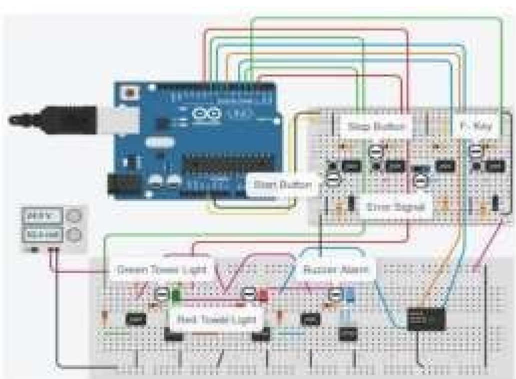

Fig. 6. Wiring Diagram

Control System Setup

The control program satisfies the truth table conditions presented in Table 2. A steady red light signifies idle (5V) or stopped (0V), where no input signal is being triggered. A steady green light means the handler is in running mode. An indefinite signal triggers the red light when both the start and stop buttons are triggered. An error signal triggers the steady red light and the buzzer when jamming occurs. When an error signal and the stop button are triggered, that means the jamming has been acknowledged by the operator, the buzzer will be turned while the red light is steady. A high priority signaling is attained when the start button is pressed during a jamming. A steady red light and buzzer alarms. When all input signals are triggered, an indefinite condition is triggered so the stop condition is of highest priority. In this state, the red signal remains steady.

Table 2. Alarm Driver Logic Table

No.	*Input signal from Handler A*	*Button State*	*Logic State*	*Priority State*	*Green Bulb*	*Red Bulb*	*Buzzer Alarm*
	Error (24 V)	Low	0				
1	Start (5 V)	Low	0	Stopped	OFF	ON	OFF
	Stop (5 V)	Low	0				
	Error (24 V)	Low	0				
2	Start (5 V)	Low	0	Stopped	OFF	ON	OFF
	Stop (0 V)	Triggered	1				
	Error (24 V)	Low	0				
3	Start (0 V)	Triggered	1	Running	ON	OFF	OFF
	Stop (5 V)	Low	0				
	Error (24 V)	Low	0				
4	Start (0 V)	Triggered	1	Stopped	OFF	ON	OFF
	Stop (0 V)	Triggered	1				
	Error (0 V)	Triggered	1				
5	Start (5 V)	Low	0	Jamming	OFF	ON	ON
	Stop (5 V)	Low	0				
	Error (0 V)	Triggered	1				
6	Start (5 V)	Low	0	Stopped	OFF	ON	OFF
	Stop (0 V)	Triggered	1				
	Error (0 V)	Triggered	1				
7	Start (0 V)	Triggered	1	Jamming	OFF	ON	ON
	Stop (5 V)	Low	0				
	Error (0 V)	Triggered	1				
8	Start (0 V)	Triggered	1	Stopped	OFF	ON	OFF
	Stop (0 V)	Triggered	1				

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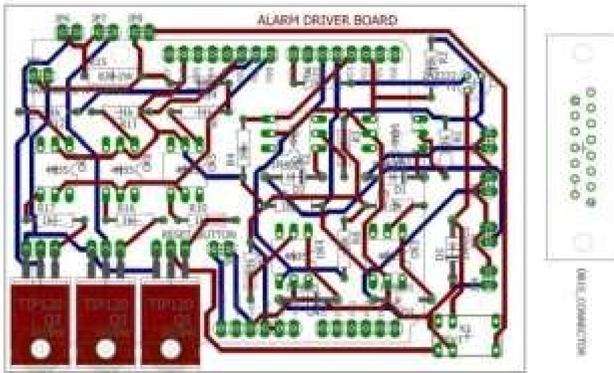

Fig. 7. Proto-shield PCB layout

The control circuit interconnection was developed by connecting the input signals to the microcontroller unit as shown in the figure 6. When the tests satisfy the condition in Table 2, the proto-shield PCB layout is developed as presented in figure 7. This circuit was designed based on the measurements on the Arduino Uno layout to make the pins compatibly installed on top of it as presented in figure 8. An enclosure was also developed to perfectly fit the components ensuring no loose parts.

Tests and Evaluation

The project evaluation was conducted by conducting more trials based on all the conditions in Table 2. The functionality test is conducted to evaluate the performance of the prototype. The measurement of the switching characteristics of the Optocoupler is carried out by adjusting the input current function while determining the output current drawn by TIP120 at collector pin when driving the load.

3 RESULTS AND DISCUSSION

Hardware Development Results

The proto-shield PCB pin headers are stacked into the female pin headers of the Arduino Uno board as shown in figure 8b. A DB15 connector was used as a transmission line for the input and output signal wires. Through this setup, wirings are being eliminated. The actual compact enclosure provided for the proto-shield PCB is presented in figure 9.

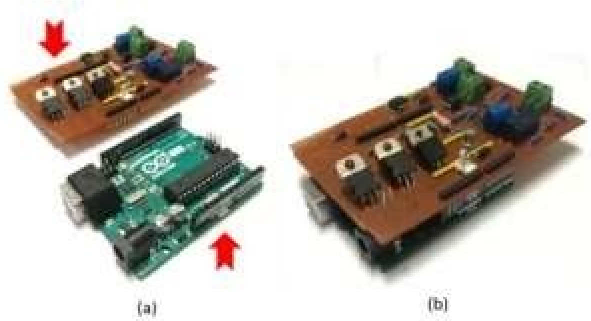

Fig. 8. Proto-shield PCB with Arduino Uno Board

Fig. 9. Actual prototype with enclosure.

Tests and Evaluation Results

Several trials were conducted in order to test and evaluate the performance of the alarm driver board. Table 3 presents the actual results of the functionality test. The Arduino was able to recognize the logic states and execute the necessary output on the alarm driver board. Additionally, a circuit protection was designed for the unwanted short circuit from the external connections of the handler (Jones et al., 1854; Lim, 2010). This was realized when the tower light cable or port was frequently plugged and unplugged when changes in setup are made. A resistor was connected in series to the tower light as designed during schematic preparation.

The test results for the 4N35 Optocoupler circuit was shown in figure 10. A trigger at the input side of 4N35 from the Arduino Uno pin 5V output signal lit the LED load and tower light in the output side of the 4N35. An 800-ohm resistor was calculated and used for 24V at 300 mA signal with the power dissipation through the circuit of 702.493 mW. The closest commercially available value selected is 820 ohms with 2W power dissipation resistor.

The circuit protection was also tested through simulation before the implementation as shown in figure 11. A switch was used as fault injection. The 820-ohm 2W resistor initiated the short circuit to the ground. The integration of 4N35 Optocoupler to the alarm driver board apparently prevents direct electrical contact. The isolation provided by the Optocoupler (C. Lee, Hsieh, Tsai, & Juang, 2017) mutually protects the microcontroller from any externally produced high voltages, such as the voltage spikes, back electromotive force (EMF), and external noise (Jenu, Sayegh, & Sapuan, 2017). Hence, the Optocouplers made the electrical devices safer, and less prone to damage.

Reliability Test Results

Test measurement to both input and output side of the Optocouplers and Darlington transistors were conducted. At the input side of the microcontroller having different input voltages, an adjustable power

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supply is used as external input voltages to pin 1, while pin 5 is set to be connected to Arduino +5V. The characterization was swept from 0 to 30 V. Simulations have been performed to correlate its result to the 4N35 specification. The typical forward voltage of 4N35 is 1.3 V. A minimum triggering voltage of 2.0 V was achieved through increasing the power supplied to the logic input to the Arduino.

Table 3. Functionality Test Result of Alarm Driver Board.

No.	Input signal from Handler A	Logic State	Green Bulb	Red Bulb	Buzzer Alarm	Remarks/Status
1	Error (24 V) Start (5 V) Stop (5 V)	0 0 0	OFF	ON	OFF	Un-triggered, Handler Idle, Steady Red only
2	Error (24 V) Start (5 V) Stop (0 V)	0 0 1	OFF	ON	OFF	Stop-triggered, Handler Stopped, Steady Red only
3	Error (24 V) Start (0 V) Stop (5 V)	0 1 0	ON	OFF	OFF	Start-triggered, Handler Running, Steady Green only
4	Error (24 V) Start (0 V) Stop (0 V)	0 1 1	OFF	ON	OFF	Start / Stop-triggered, Handler Stopped, Steady Red only
5	Error (0 V) Start (5 V) Stop (5 V)	1 0 0	OFF	ON	ON	Error, Handler Jamming, Steady Red w/ Alarm ON
6	Error (0 V) Start (5 V) Stop (0 V)	1 0 1	OFF	ON	OFF	Error / Stop-triggered, Handler Stopped, Steady Red only
7	Error (0 V) Start (0 V) Stop (5 V)	1 1 0	OFF	ON	ON	Error / Start-triggered, Handler Jamming, Steady Red w/ Alarm ON
8	Error (0 V) Start (0 V) Stop (0 V)	1 1 1	OFF	ON	OFF	Error / Start / Stop-triggered, Handler Stopped, Steady Red only

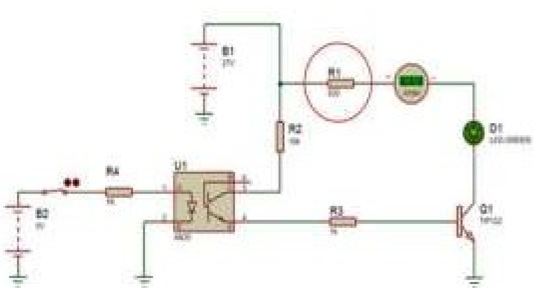

Figure 10. Test Circuit for Alarm Driver Board

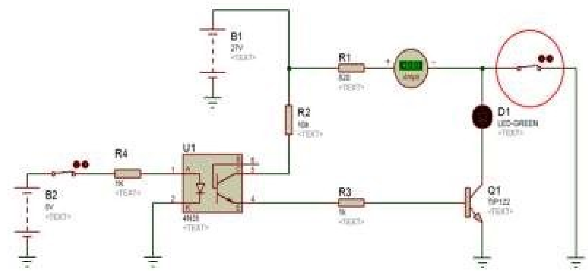

Figure 11. Test Circuit for Circuit Protection

The Optocoupler worked well over a wide range of input voltages without degrading its performance (Shi, Lu, Chen, & Feng, 2014). Figure 12 shows that varying the input voltage or current at input pin 1 have no significant effect on the current drawn at output pin 5 during measurement done. For the output side, another 4N35 Optocoupler isolated the load side from the microcontroller. Through the use of an adjustable power supply as an external source connected to the pin, the current drawn was determined and its effect on driving the load, tower light and buzzer

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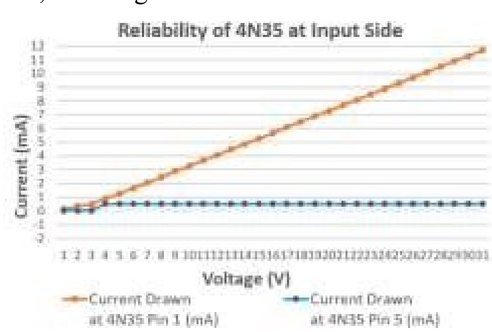

Figure 12. VI curve input module

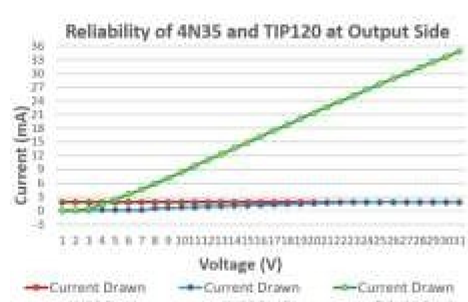

Figure 13. VI curve output module

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4 CONCLUSIONS

The installation of the alarm driver board which satisfies logical conditions for control successfully initiated the tower light and buzzer for the legacy handlers in standard configuration. The protoshield PCB eliminates the possible loose connections compared to wired systems. The Optocouplers and Darlington transistors successfully translated signals that are recognized by the controller. It also serves as a protection for both input and output to the controller. Through the integration of these components. The measurement results demonstrated the system's functionality and reliability with a range of input signal voltages. The alarm driver board developed is recommended for implementation to other types of handlers which in turn can bring impact to the closure of FET issues of legacy handlers related to tower light problem. The result of enabling the tower light capability to those legacy handlers will provide the visual and audible alarm which is more beneficial to the assigned operators. This initiative can produce a more reliable equipment status and a high equipment utilization that guarantees performance and quality of the test process.

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