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Design and Implementation of a Visible Light-Based Pest Stinger System

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Abstract – *The agricultural yield in Indonesia has been declining, partly due to shrinking farmland. To address this issue, urban farming has been developed as a solution. However, in urban farming, there is a problem where the leaves of vegetables are infested by insect pests, causing damage to the leaves. Therefore, pest control is necessary in the farming area. One alternative for controlling insect pests is by applying high-voltage electricity to the pests, which will kill them by electric shock with a voltage of around ±1 kV. A Joule thief circuit is designed to increase the input voltage below 9 volts to an output voltage of ±1 kV. There are also supporting components, such as a lamp that emits ultraviolet light, to attract the pests. A monitoring system is also designed to allow operators to know the environmental conditions of the vegetable farm, such as soil moisture, air humidity, light intensity, and notifications if the insect carcass container is full. During testing of the trap, there was an issue with the internet connection, so a backup circuit was made to keep the device running according to the schedule without an internet connection. This pest trap was tested for 5 days, and the number of trapped pests increased each day, leading to the conclusion that this device effectively traps pests.*

Keywords – *pest insects; sting circuit; monitoring; urban farming; Joule thief.*

I. Introduction

HUMAN needs are generally classified into three categories: clothing, food, and shelter [1]. Food needs are met through agriculture, livestock, and fisheries [2]. Agriculture in Indonesia plays a vital role in the economy, as evidenced by the data showing that 3.49% of Indonesia's workforce is employed in agriculture [3].

However, agricultural yields in Indonesia have declined due to the lack of agricultural land, leading to the creation of urban farming [4], one of which is in Tanikota. Tanikota is an urban agriculture initiative that applies horticulture as well as the cultivation of garden plants like vegetables. However, urban agriculture also faces declining crop yields, one of the reasons being the damage caused by pest attacks [5].

To prevent this decline in agricultural output, pests must be eradicated. To combat pests, some farmers use pesticides on their crops. However, pesticides can poison consumers due to pesticide residue and are not environmentally friendly, as they can harm ecosystems. The National Pest Management Association, a non-profit organization based in Virginia, United States, has tried to reveal why insects are attracted to light. First, insects rely on light to guide their navigation and movement [6].

The second theory suggests that insects approach light because they are searching for food. This is based on the fact that moths, for example, feed on nectar from flowers, which are known to reflect ultraviolet (UV) light. Some light bulbs emit small amounts of ultraviolet light, causing hungry insects to mistake the bulbs for flowers.

This behavior, referred to as positive phototaxis, is well documented in entomological research and has become a key consideration in pest control strategies [9].

Once it was discovered that pests are attracted to ultraviolet light, a device was needed to kill these pests by shocking them with a high-voltage sting circuit. Pest insects can die when exposed to a current ranging from 1 mA to 5 mA [7].

Therefore, a pest exterminator using ultraviolet light and a high-voltage sting circuit was designed to

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eliminate pests in vegetable fields in Tanikota. The sting circuit is more energy-efficient, with the sting consuming only 13.47 W of power [8].

The design of energy-efficient pest traps is increasingly important as urban farming systems aim to balance productivity with sustainability [10]. Moreover, the combination of targeted pest elimination and low power consumption aligns with the principles of smart agriculture and Internet of Things (IoT) applications [11].

In addition to serving as a pest exterminator, this tool is also designed to monitor the environment of vegetable fields, with the goal of assisting operators in overseeing the vegetable fields. The conditions to be monitored include air temperature and humidity, as well as soil moisture in the vegetable fields. The data from the monitoring can be used to determine the environmental conditions that increase insect pest activity in the garden.

Recent studies have shown that pest behavior is highly correlated with microclimate variations such as humidity and light intensity, highlighting the value of real-time environmental monitoring in integrated pest management [12].

II. Research Methods

i. Shock Net

The shock net, which functions to kill pests, requires an electric circuit with a DC voltage output [13]. To kill pest insects, a voltage of 1 kV is needed, which is very high and requires a substantial input. However, there are several components that can convert a low input voltage into a high voltage, one of which is the joule thief circuit and the full-wave rectifier bridge circuit.

To increase voltages, the shock net requires a transistor, especially of the NPN-type, which acts as an amplifier. The current flowing from the collector to the emitter is an accumulation of the collector current with the base current, thereby increasing the voltage at the base by making the emitter an amplifier [14].

ii. Full-Wave Rectifier Circuit

The rectifier bridge aims to convert AC electricity into DC output, where the rectifier bridge consists of diodes that eliminate the negative cycle and turn it into a positive cycle. A capacitor with a sufficiently large capacitance is used to smooth out the wave. This is due to the extended discharge process of the capacitor, making it appear as though the amplitude of the wave has been flattened [15]. The rectifier bridge circuit can be seen in Figure 1.

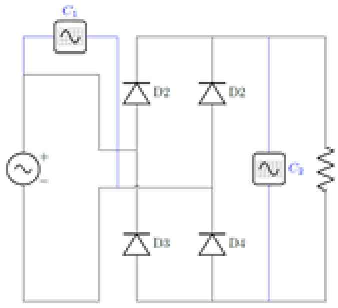

Figure 1: Full-Wave Rectifier Circuit

iii. Linear Regression

Linear regression measures the degree of relationship between two or more variables in the form of a function. Linear regression is divided into several types, such as simple linear regression, multiple regression, and polynomial regression [16].

Simple linear regression is commonly used for sensor calibration, where there is only one independent variable to obtain the dependent variable, as shown in Equation (2).

$$y = mx + b \tag{1}$$

In linear regression, there is an R^2 value derived from Equation (2), which is a statistical measure that indicates whether the data fits the regression model or not [17]. The interpretation of the R^2 value is as follows:

1. $R^2 = 0$: The regression model does not explain the variability in the data at all.
2. $0 < R^2 < 1$: The regression model explains some of the variability in the data.
3. $R^2 = 1$: The regression model perfectly explains all the variability in the data.

iv. ESP32

Figure 2 shows the ESP32, which was developed by Espressif Systems, a company based in Shanghai, China. The ESP32 is a microcontroller that uses the Tensilica Xtensa LX6 microprocessor as its core [18].

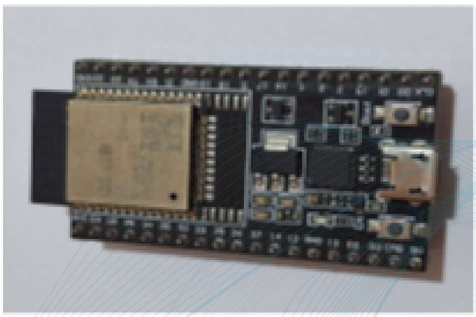

Figure 2: ESP32 V4 Microcontroller

In this pest exterminator, the ESP32 microcontroller is used as the main controller to manage the entire program. The components controlled by the ESP32 include the RGB light, motor driver, and various sensors.

v. RGB Light

The RGB light is a lamp that can emit a combination of colors based on the desired R (red), G (green), and B (blue) values, as shown in Figure 3. The function of the RGB light is to emit a color spectrum that resembles ultraviolet light, which attracts pests, causing them to approach the pest exterminator.

Figure 3: RGB Smart Light for UV Spectrum Simulation [19]

In the design of this pest exterminator, the RGB light is used because it has a 10W specification and a color spectrum that can be adjusted via Bluetooth.

vi. RTC Module

The Real-Time Clock (RTC) module is a device that can measure time digitally. Additionally, pull-up resistors are used for the I2C communication lines, and capacitors help stabilize the voltage. However, the battery charging circuit is less practical and may require additional considerations. There are two types of RTC modules available on the market: DS1302 and DS1307 [20]. In this design, the DS1307 RTC module is implemented, as illustrated in Figure 4.

Figure 4: RTC Module DS1307

vii. DHT11 Sensor

The DHT11 sensor functions as a humidity and temperature measurement sensor, as shown in Figure 5. The humidity sensor features two electrodes with a moisture-absorbing dielectric material. As humidity varies, the capacitance changes, which is detected and converted into digital data by the IC. For temperature sensing, the sensor utilizes an NTC thermistor whose resistance decreases as temperature increases [21].

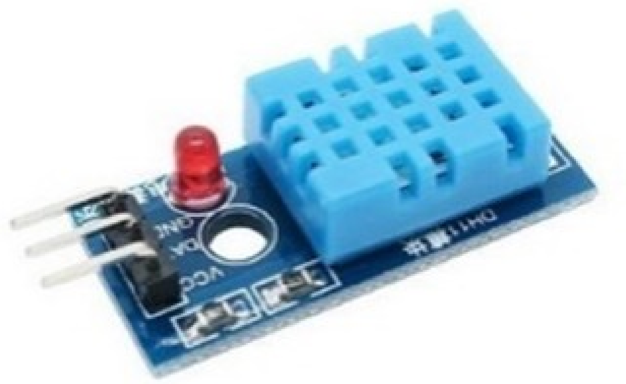

Figure 5: DHT11 Temperature and Humidity Sensor

viii. Ambient Light Sensor

The Ambient Light Sensor measures the intensity of ambient light, helping determine if pests are more attracted to moonlight during full moons. This sensor's specifications include a voltage range of 2.7V to 6V DC, current consumption of 7mA, detection range of 0–200 klx, and I2C communication. Figure 6 shows the DFRobot ambient light sensor used in the system [22].

Figure 6: DFRobot Ambient Light Sensor 200klx

ix. Pest Exterminator Design

The initial design of the pest exterminator can be seen in Figure 7. Originally, it used a 2-inch iron pole with a height of 2 meters. However, this was replaced with four aluminum profile poles to enhance stability and reduce the risk of toppling due to wind.

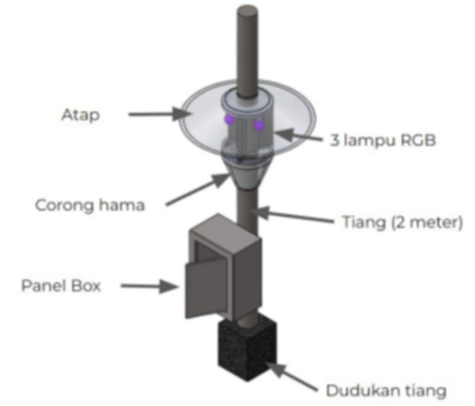

Figure 7: Initial Design of the Pest Exterminator

After revising the structural elements, the final version of the exterminator system was designed, as shown in Figure 8. A violet RGB lamp attracts pests, which are then shocked by the electric net surrounding the lamp. The net is placed 1 meter above the ground and covered with a pyramid-shaped roof made of plywood coated with aluminum foil to protect it from rain. The entire structure is supported by 1.5-meter aluminum T-slot 2020 profiles.

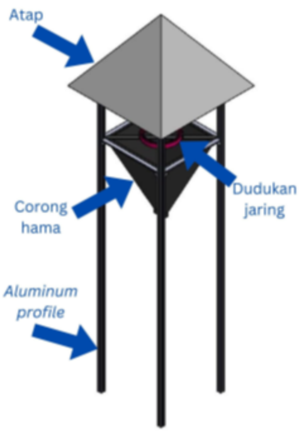

Figure 8: Final Design of the Pest Exterminator

The net holder, printed using an Ender 3 3D printer from ABS filament, consists of two parts (left and right) and features an outer diameter of 16 cm and an inner diameter of 13.5 cm. Figure 9 illustrates the top-down view of the net. The outer net is positively charged, and the inner net is grounded. When pests approach the light, they may contact both nets, allowing current to flow and causing an electric shock that kills them [23]. The remains fall into a funnel made from 3 mm Infraboard with an 11 cm² hole at the end, which connects to a pest bottle for collection.

Figure 9: Top View of Pest Exterminator Net Design

x. Joule Thief Circuit in the Device

The Joule thief circuit, shown in Figure 10, functions as a voltage multiplier using an inductor [24]. The working principle of this circuit is based on a blocking oscillator, which utilizes discrete electronic components to generate a free-running signal. The main components are a BJT (Bipolar Junction Transistor) and a transformer [23].

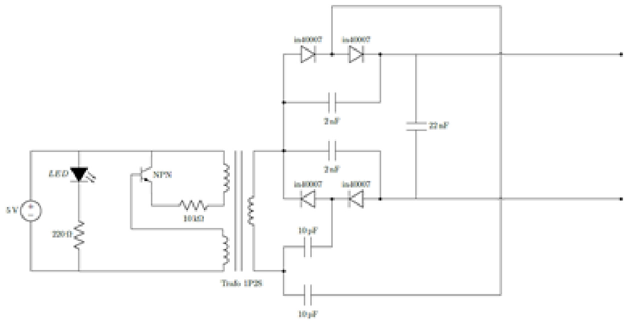

Figure 10: Schematic of the Joule Thief Circuit

As depicted in Figure 10, the NPN transistor acts as an oscillator that transforms DC input into an AC waveform. The charger transformer has three pins—primary, secondary, and feedback—which are essential in stepping up the voltage from the transistor. The interaction between the transistor and the transformer creates the Joule thief effect, boosting voltages from inputs lower than 9V DC.

When the circuit is powered, current flows from the power source through a resistor to the secondary coil and into the base-emitter junction, activating the transistor. This allows the collector current to flow through the primary coil. The resulting AC is rectified back into DC through a diode-capacitor network. The diode used is IN4007, capable of withstanding voltages up to 1000 volts, which is critical for the system's safety and reliability [25].

xi. PCB Schematic

To integrate all components, a control circuit was developed using a PCB layout designed to work with the

ESP32 microcontroller. This circuit facilitates relay control and sensor data reception. Figure 11 illustrates the wiring and interconnection between the components placed inside a protective plastic enclosure in the exterminator system.

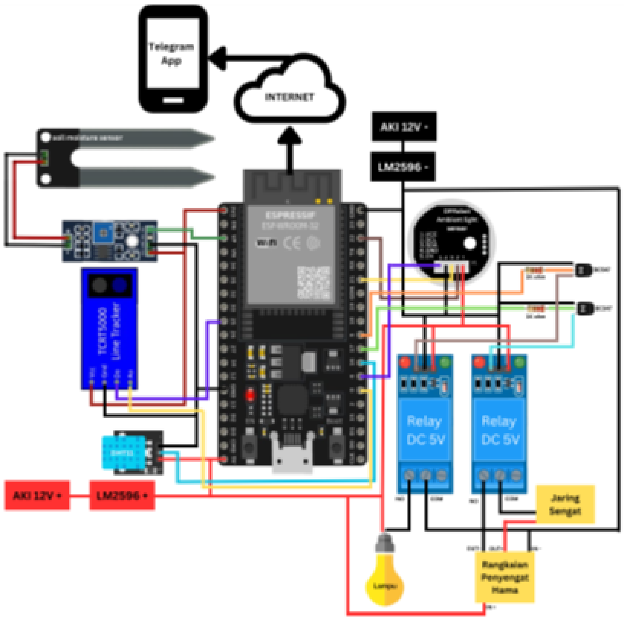

Figure 11: PCB Schematic and Component Wiring

Based on Figure 11, the relay used is rated at 5V. However, the ESP32's GPIO pin outputs only 3.3V, insufficient to directly trigger the relay. Therefore, the output from the ESP32 is connected to a 1000 Ω resistor leading to the base of an NPN transistor, which then functions as a switch. This allows sufficient current to flow through the collector-emitter junction, activating the relay effectively through the 5V power supply.

III. Results and Discussion

From the existing shock circuit, component testing was conducted to analyze the transformer's voltage ratio using a 3.6V battery as input. The primary pin (P) had a winding resistance of 0.8 Ω and a peak-to-peak voltage (Vpp) of 80V. The secondary pin (S) exhibited a winding resistance of 162.6 Ω with a Vpp exceeding 760V, which surpassed the measurement capacity of the oscilloscope. The feedback pin (F) had a winding resistance of 2.1 Ω and a Vpp of 292V.

The output current of the shock circuit was measured to exceed 5 mA, as shown in Figure 12, where the multimeter needle surpassed the display limit. Additionally, the output voltage exceeded the measuring device's 1000V maximum.

Calibration of the ambient light sensor was conducted by comparing it with a LUX meter. Data was collected from 10 brightness samples (0% to 100%)

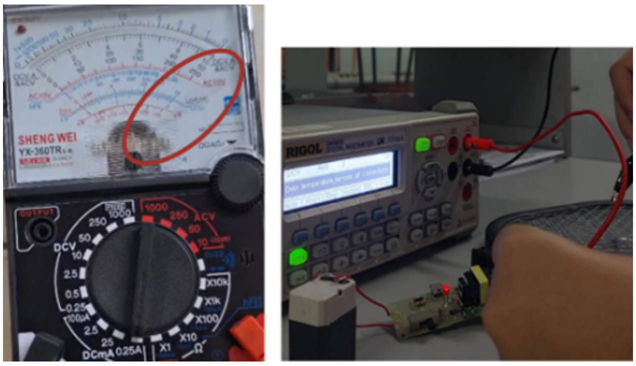

Figure 12: Multimeter reading (left) and excessive voltage output (right)

with intervals of 10%. The comparison results are presented in Table 1.

Table 1: Calibration of Sensor and LUX Meter

Brightness	LUX Meter (y)	Sensor (x)	$x \cdot y$	x^2	Calibrated Value
0%	0	0.50	0	0.25	−1.4015
10%	52	52.92	440	2800.53	52.0145
20%	52	52.92	576	2800.53	52.0145
30%	63	63.76	724	4065.34	63.0604
40%	85	84.67	869	7169.01	84.3677
50%	104	102.82	1008	10571.95	102.863
60%	129	130.03	1151	16907.80	130.590
70%	149	149.18	1278	22254.67	150.103
80%	172	171.36	1425	29364.25	172.705
90%	179	176.40	—	31116.96	177.841
100%	179	176.40	—	31116.96	177.841
Total	1164	1160.46	—	159037.60	158167.99

The calibration resulted in a regression model as shown in Figure 13, with the linear regression equation:

$$y = 1.0154x - 1.348 \tag{2}$$

and an R^2 value of 0.9997. According to (2), the model fits the calibration data very well.

Figure 13: Linear regression of LUX sensor calibration

Testing of the pest exterminator was conducted over five days. However, the planned test site in the front garden had to be moved to the back garden. Consequently, a backup circuit was implemented, as shown in Figure 14. The key difference in this backup system is the inclusion of the RTC module to manage active operation time.

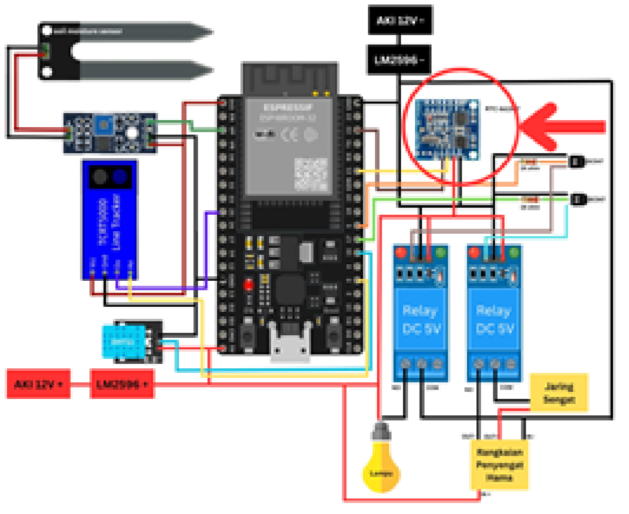

Figure 14: Backup system with RTC module

From the backup circuit, insect carcasses were collected, although some species could not be identified due to being electrocuted. The results from the first day of testing are shown in Figure 15.

Figure 15: Insect carcasses on the first day of testing

Over the course of five days, insects of various sizes were collected. A notable increase in insect carcasses was observed from the first to the final day of testing, as illustrated in Figure 16.

During testing, there was a Wi-Fi signal issue—the Tanikota network could not reach the test garden location. Consequently, environmental sensor data was only gathered on the last night by utilizing a smartphone hotspot. Meanwhile, the device remained active for four days based on the real-time clock (RTC) configuration. A sample notification message sent by the ESP32 to Telegram after five days is displayed in Figure 17.

From the environmental data transmitted by the ESP32 to the Telegram Bot, the following figures were generated: air temperature (Figure 18), air humidity (Figure 19), and light intensity (LUX) values (Figure 20).

Figure 16: Insect carcasses on the last day of testing

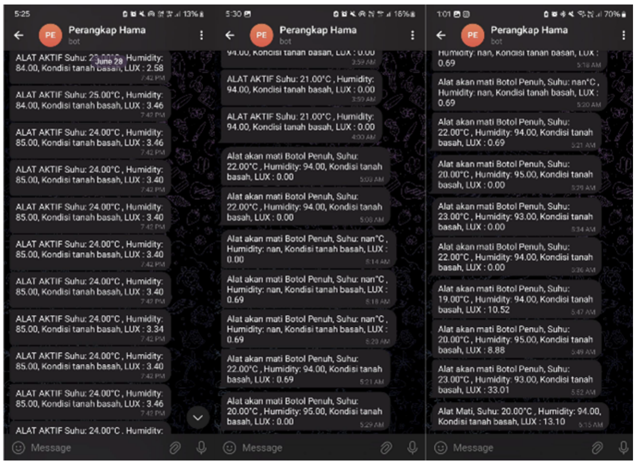

Figure 17: Telegram notification sent from ESP32

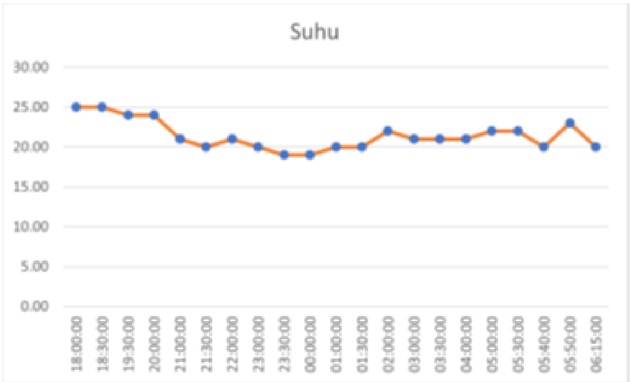

Figure 18: Air temperature data in the test garden

From this data, it can be concluded that the nighttime air temperature ranged from 19–25°C, relative humidity was between 77%–99%, and the light intensity remained low. This confirms that there was no interference from external light sources that could distract insects from being attracted to the pest exterminator light. These environmental conditions are promising and can be monitored further on a daily basis to analyze insect behavior and activity patterns at night.

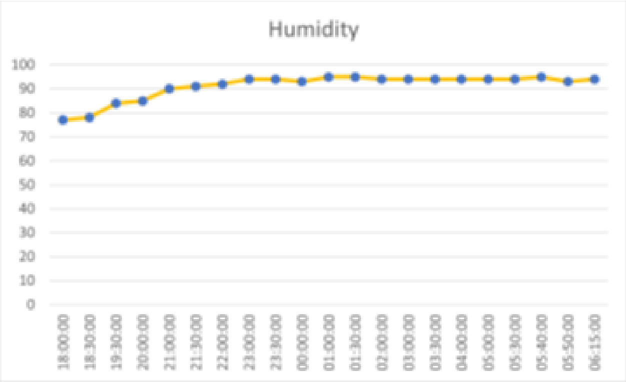

Figure 19: Air humidity data in the test garden

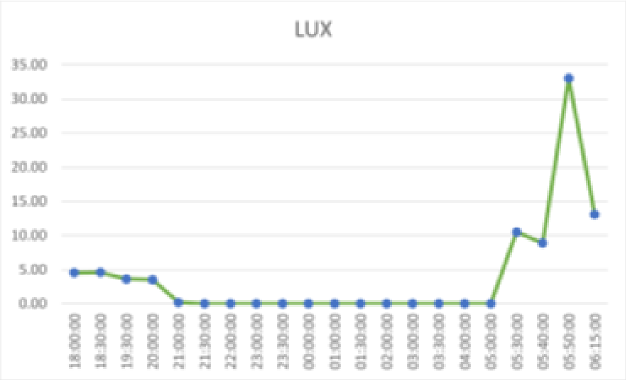

Figure 20: LUX value data in the test garden

IV. Conclusion

The conclusion of this study is that the integrated monitoring system in the pest exterminator performed effectively, as evidenced by the consistent environmental condition updates sent via Telegram Bot. The monitored data included air temperature, humidity, soil moisture, light intensity (LUX), and the status of the insect collection bottle. Furthermore, the pest exterminator demonstrated effective operation by successfully neutralizing pests, as confirmed by the increasing accumulation of insect carcasses during the testing period.

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