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An Infrared Emitter Driver Circuit of SAT for MILES Application

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ABSTRACT

This paper presents a novel infrared (IR) emitter driver circuit designed for the Small Arm Transmitter (SAT) in Multiple Integrated Laser Engagement System (MILES) applications. The primary objective is to maximize the IR emitter power output while maintaining a high switching frequency of 38 kHz, as required by the NEC standard IR communication protocol. The driver circuit is compatible with low-level voltage microcontrollers (MCUs) and utilizes a low-side MOSFET configuration for simplicity and ease of implementation. Practical design considerations, such as the characteristics of the MOSFET and IR emitter, are discussed in detail. The proposed circuit incorporates a pulse shaping network consisting of a sweep-out circuit to improve the falling time and a peaking circuit to reduce the optical rise time. A non-inverting push-pull transistor amplifier is employed to drive the MOSFET gate efficiently. Simulation results demonstrate that the driver circuit can produce satisfactory voltage and current pulse shapes for the IR emitter, achieving a high-power output of 4.5 W without phase shifting. The circuit component values can be adjusted to meet higher power output requirements. This research aims to contribute to the development of advanced MILES technology for realistic military training scenarios.

Keywords: small arm transmitter, IR led MOSFET driver, push pull transistor, high power IR emitter

1. INTRODUCTION

MILES is a training technology utilized in military and law enforcement applications to simulate combat scenarios. This system enables realistic training exercises without using live ammunition. The infrared transmitter circuit, which is a component of the device known as the SAT (Small Arm Transmitter), plays a crucial role in MILES technology [1]. An SAT emits an infrared beam that simulates the discharge of a weapon. Infrared transmitters require design parameters that provide sufficient power and range to accurately simulate the engagement of targets, while maintaining a compact and unobtrusive form factor. [2]. The SATs are integrated with weapons to ensure that the simulated firing aligns with the actual weapon's aiming and firing mechanisms. MILES aims to provide a highly realistic training experience, enabling participants to engage in simulated combat scenarios that closely approximate real-world conditions.

To ensure the efficient transmission of PID (Player ID) data in the MILES and optimize the IR beam power, the design of the driver circuit for pulsating the IR diode emitter should focus on the following key aspects: IR Diode Emitter Characteristics, Driver Circuit Design, Pulse Shaping and Timing, and Thermal Management. The selection of an appropriate IR diode emitter is critical. High-power IR diodes that can achieve peak optical power outputs of up to 16 W are suitable for MILES applications[2]. The emitter should also have fast modulation capabilities, with a modulation depth larger than 90% at frequencies up to 10 Hz, as mentioned in [3]. The driver circuit should be designed to maximize the power delivered to the IR diode emitter while maintaining a compact and efficient design. [4], [5] discuss the use of switch-mode power supplies and pulse-width modulation (PWM) techniques to achieve high-efficiency power conversion and control of the IR diode output power. A high-power IR diode emitter can generate significant heat, which affects its performance and reliability. The driver circuit design should incorporate effective thermal management strategies such as heatsinks or active cooling to maintain the optimal operating temperature of the emitter.

Rapid-response DC/DC converters are essential for generating time-varying output voltages, particularly in

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applications such as MILES (multiple integrated laser engagement systems) that necessitate precise and rapid control of IR LED power supplies. Several sophisticated control techniques have been developed to achieve a swift dynamic response in DC/DC converters. One such approach is the virtual direct power control (VDPC) scheme with a single-phase-shift control for dual active bridge (DAB) DC-DC converters. This method integrates direct power control with feedforward control strategy, resulting in the absence of overshoot and rapid transient response for the output voltage during load or input voltage disturbances and start-up phases. [6] Another technique is the continuous non-singular terminal sliding mode control (CTSMC) based on finite-time disturbance observer, which achieves rapid transient responses and robust suppression of time-varying disturbances. [7]. Certain approaches have focused on increasing the switching frequency to enhance the dynamic response. For example, an integrated DC-DC converter switching above 100 MHz can significantly reduce the footprint of inductors and capacitors, while improving the droop response. [8]. Nevertheless, this approach may be constrained by the maximum input voltage of the advanced digital CMOS processes. Despite these technological advancements, there is a dearth of optimized circuit designs specifically tailored for high-power infrared emitters in MILES applications. Moreover, the compatibility of the driver circuit with low-power embedded systems is of significant importance. When low-power embedded systems such as the ESP32 or other microcontrollers (MCUs) operating at 3.3V, there are several reasons for using a driver circuit to control high-power infrared (IR) emitters. Most low-power MCUs are designed to output limited current, typically in the range of a few milliamperes (mA). High-power IR emitters often require substantially higher currents (tens to hundreds of milliamperes) to operate effectively and achieve the maximum output intensity. The driver circuit can provide the necessary current without damaging the MCU.

This paper proposes a novel IR emitter driving circuit that can provide the maximum power needed for long-distance detectable IR beams for MILES applications. The IR beam, which contains the PID modulated with 38KHz modulation frequency to meet a standard NEC IR communication protocol. A driving circuit can be interfaced with 3.3V embedded systems.

2. RESEARCH SIGNIFICANCE

This work explores the research significance in a variety of critical areas, commencing with its proposal of a novel circuit design. Specifically, it introduces a new infrared (IR) emitter driver circuit tailored for Small Arm Transmitter (SAT) devices, which are employed within Multiple Integrated Laser Engagement Systems (MILES) used for military training. This innovative design addresses a notable gap in optimized circuit designs for high-power IR emitters within MILES applications, highlighting a need for advanced solutions in this specialized field.

Another key aspect of the research focuses on compatibility with low-power systems. The proposed driver circuit is crafted to interface seamlessly with 3.3V embedded systems, like ESP32 microcontrollers. This compatibility is particularly significant as it enables the use of low-power, compact microcontrollers to control high-power IR emitters, thus broadening the application capabilities of such technologies.

In terms of performance, the manuscript details the circuit's ability to maximize power output for IR beams detectable over long distances. This feature is crucial for ensuring realistic combat simulations within MILES operations, as it enhances the reliability and fidelity of training scenarios. Additionally, the design incorporates pulse shaping optimization techniques, which compensate for the intrinsic behavior of IR emitters while maximizing their power output. Techniques such as sweep-out and peaking circuits are employed to improve rise and fall times, further enhancing performance.

The paper also delves into detailed analysis and simulation, providing an in-depth examination of the characteristics of MOSFETs and IR LEDs, along with comprehensive circuit simulations. Such detailed analysis offers valuable insights into the behavior and performance of the proposed design, which are essential for understanding its operational efficiencies and potential improvements.

Practical considerations are another focal point of the manuscript, addressing real-world challenges in designing IR emitter drivers. Issues such as thermal management, switching speed optimization, and compatibility with standard IR communication protocols are thoroughly examined to ensure the circuits are viable in practical applications.

The research holds potential for significantly improving military training systems, as enhancements in the performance of SAT devices could lead to more realistic and effective simulations utilizing MILES technology. The adaptability of the circuit design, which allows for adjustment of component values to meet different power output requirements, underscores its versatility for various MILES applications.

In comparison to existing approaches, this study distinguishes itself by focusing specifically on MILES applications, rather than more general IR emitter driver designs. Additionally, it highlights the integration with low-power embedded systems, a feature not always addressed in current high-power IR driver designs. The inclusion of detailed simulation results and analysis further differentiates this study, offering a comprehensive understanding of the circuit's behaviour and substantiating its contributions to the field.

3. PRACTICAL DESIGN CONSIDERATIONS

3.1 MOSFET

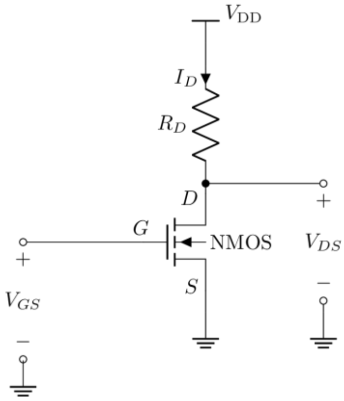

Fig 1. NMOS basic circuit

MOSFET (semiconductor field-effect transistors (MOSFETs) are a type of transistor used for switching and amplifying electronic signals. It is a fundamental component of modern electronic devices. MOSFETs come in two basic types: N-type (NMOS) and P-type (PMOS). This discussion focuses on the N-type MOSFET, which is formed by creating a channel composed of n-type semiconductor material between two n+ regions, known as the source and the drain, with a gate electrode isolated by a thin oxide layer. In an N-type MOSFET, when a positive voltage is applied to the gate (relative to the source), it attracts electrons toward the gate, inverting the p-type substrate underneath the gate (G) into an n-type channel, allowing current (I_D) to flow between the drain (D) and source (S) terminals. The amount of current flow depends on the gate-source voltage (V_{GS}) and the drain-source voltage (V_{DS}), see Fig 1.

There are two regions in the I_D versus V_{DS} curve: active and ohmic regions. The active region (also called saturation region) is where the MOSFET operates as an amplifier. In this region, the drain current (I_D) becomes relatively constant (saturates) and is primarily controlled by the gate voltage (V_{GS}). This occurs when V_{DS} is larger than $V_{GS} - V_T$ (threshold voltage), effectively "pinching off" the channel at the drain end.

$$V_{DS} \geq V_{GS} - V_T \quad (1)$$

The drain current I_D is computed using

$$I_D = k(V_{GS} - V_T)^2 \quad (2)$$

Where k is the conduction parameters ($\frac{\mathrm{m}}{\mathrm{V}^2}$).

Despite the name "pinch-off," current continues to flow due to carrier drift over the pinch-off point, resulting in a saturation current that is relatively stable with variations in V_{DS}. In digital applications, this region is used when the MOSFET functions as more than just a simple switch, such as in analog circuits or linear applications.

In the ohmic region, the MOSFET behaves like a resistor, and the current through it increases linearly with an increase in V_{DS}. This region occurs when V_{DS} is less than $V_{GS} - V_T$.

$$V_{DS} \leq V_{GS} - V_T \quad (3)$$

and the drain current I_D is expressed as

$$I_D = k(2(V_{GS} - V_T)V_{GS} - V_{DS}^2) \quad (4)$$

The MOSFET is fully "on" in this region, and thus it is used for switching applications. This is because the resistance between the drain and source is low, and the device can carry high currents efficiently when turned on by the gate voltage. MOSFETs are utilized as switches in this region, particularly in applications like power electronics, digital circuits, and microcontroller output switching, due to their ability to quickly switch on and off and handle high current loads with minimal power loss. For the infrared driver in SAT system, the NMOS is used for a low-side switching device.

3.2 IR LED

An infrared (IR) emitter is a device that produces infrared light, which is electromagnetic radiation with wavelengths longer than visible light but shorter than microwaves. IR emitters are utilized in various applications, including remote controls, optical communication, night vision systems, and IR sensing. These emitters typically comprise light-emitting diodes (LEDs) fabricated from semiconductor materials such as gallium arsenide (GaAs), which are designed to emit IR light when an electric current passes through them. To comprehend the characteristics of the IR emitter, an approximated model should be examined. The IR emitter can be modeled as a diode. Incorporating capacitance and inductance in the model of a high-power infrared (IR) emitter can substantially enhance the accuracy of the approximated model, particularly regarding switching behaviour, transient response, and frequency characteristics. The junction capacitance is a crucial aspect of the diode model and can influence the switching speed. It is frequently represented as a parallel capacitor in the circuit. Additional parasitic capacitances may arise from the layout and packaging of the IR emitter, often including traces and leads. These can also be modeled with small capacitances added in relevant locations in the circuit. Series inductance occurs due to leads and traces leading to the IR emitter. It can produce significant effects in high-frequency applications by introducing delays and generating voltage spikes during switching transients. Similar to capacitance, there can be additional inductance from the connections and layout in the circuit. This inductance can affect the performance, especially under high-speed switching conditions.

For a practical purpose, a Spice model of the infrared emitter provided by the manufacture was used to study the switching behaviour in high frequency, in particular, we used IR emitter SFH4715S from AMS-OSRAM. A simple closed loop circuit in Fig 2 was made for simulation. The transient behaviour of rise time and fall time was observed by varying R_1 value.

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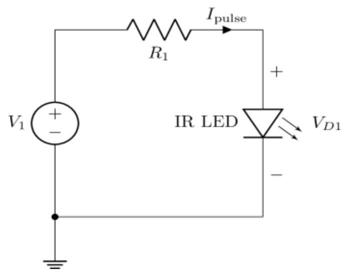

Fig 2. A simple circuit for observing the behaviour of the IR emitter for high frequency switching

V_1 is the 5V pulse voltage, with $T_{\text{on}} = 20\text{ns}$ and signal period of 40ns, thus signal with the frequency of 25MHz. Fig 3 shows the transient response IR emitter voltage and current, given $R_1 = 50\Omega$. The forward current was starting to pass through the emitter when the V_1 was about 0.8V. The forward current peaks very fast at 0.09A, before the IR LED voltage drop V_{D1} begins to rise and peaks at 2.6V. V_{D1} starts to drop after 10ns delay from the time of the input voltage reach 0V.

The sudden change from 5V to 0V of the input voltage, plunges the current down to −0.04A, which means the current flows in the reverse direction. This behaviour may due to junction capacitor and series inductor in the model. Reducing the value of R_1 will increase the current in the loop. The overshoots and undershoots are started to appear, as seen in Fig 4. However a significant improvement of the rise and fall times in V_{D1} response are observed. Pushing more current in the loop, more prolonged oscillation is expected. Important note that can be observed from Fig 5 is that the IR emitter voltage drop V_{D1} peaks near the maximum input voltage.

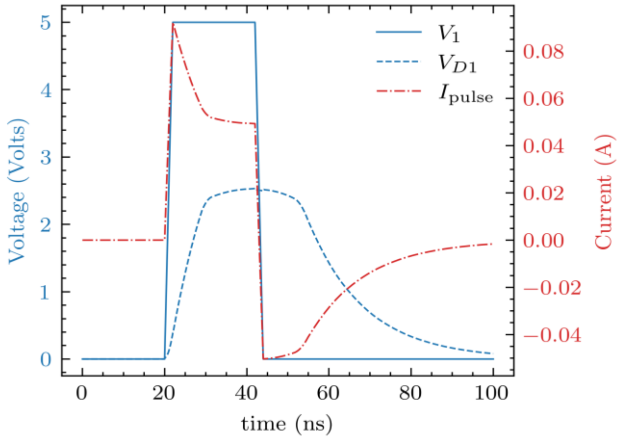

Fig 3. $R_1 = 50\Omega$

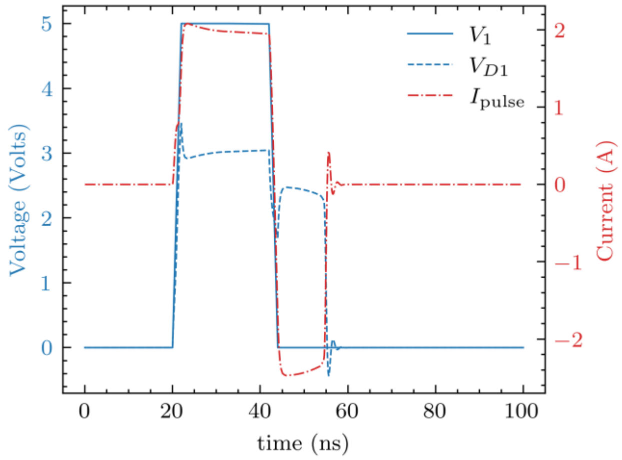

Fig 4. $R_1 = 1\Omega$

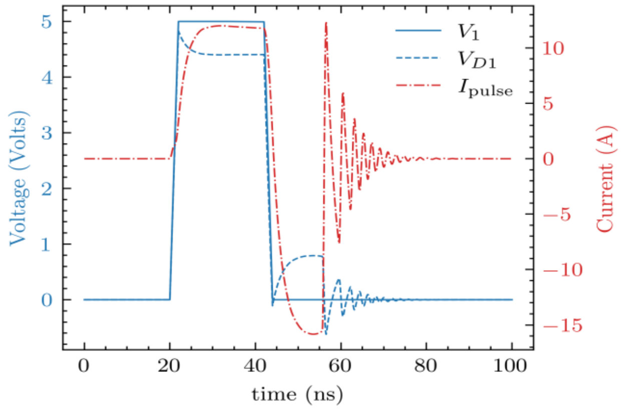

Fig 5. $R_1 = 0.5\Omega$

3.3 PUSH PULL AMPLIFIER

A push–pull amplifier is a type of electronic circuit that uses a pair of active devices that alternately supply current to, or absorb current from, a connected load (Fig 6). This kind of amplifier can enhance both the load capacity and switching speed. Push–pull outputs are present in TTL and CMOS digital logic circuits and in some types of amplifiers, and are usually realized by a complementary pair of transistors, one dissipating or sinking current from the load to ground or a negative power supply, and the other supplying or sourcing current to the load from a positive power supply.

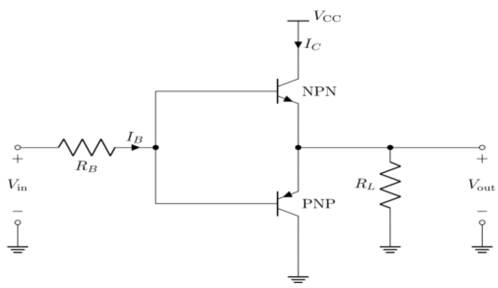

Fig 6. Push-Pull amplifier basic circuit

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Two matched transistors of the same polarity can be arranged to supply opposite halves of each cycle without the need for an output transformer, although in doing so the driver circuit often is asymmetric and one transistor will be used in a common-emitter configuration while the other is used as an emitter follower. The totem-pole amplifier can source and sink higher currents than single-transistor output stages, making it suitable for driving low-impedance loads. The output voltage swing (V_{out}) can ideally range from ground (0V) to V_{CC} (the supply voltage). However, saturation voltages ($V_{CE(\text{sat})}$) can limit the output swing.

$$V_{\text{out}} = V_{CC} - V_{CE(\text{sat})} \quad (5)$$

Proper biasing is essential to ensure that transistors operate efficiently. Calculate the base current (I_B) for each transistor to ensure they are driven into saturation.

$$I_B = \frac{I_C}{\beta} \quad (6)$$

Where (I_C) is the collector current, and (β) is the current gain of the transistor. The collector current can be estimated based on the load R_L.

$$I_C = \frac{V_{\text{out}}}{R_L} \quad (7)$$

The duration required for transistors to transition between on and off states can be critical in high-speed applications. The turn-on time (t_{on}) and turn-off time (t_{off}) are influenced by the base and collector capacitances, resistances, and electromotive force (EMF) values. For capacitive loads,

$$t_{\text{on}} \approx R_B C_B \ln\left(\frac{V_{CC}}{V_{CC} - V_{BE(\text{sat})}}\right) \quad (8)$$

Where R_B is the base resistance, C_B is the base-emitter capacitance, $V_{BE(\text{sat})}$ is the base-emitter saturation voltage. The output impedance Z_{out} can be calculated based on the transistor's characteristics. Ideally, it is low to drive loads effectively; for large signal conditions, it can be modelled as:

$$Z_{\text{out}} = r_e \parallel R_L \quad (9)$$

where r_e is the small-signal emitter resistance.

4 CIRCUIT DESIGN AND SIMULATION RESULTS

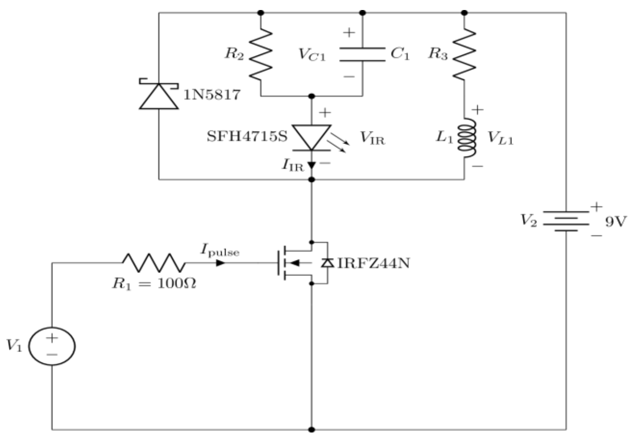

Fig 7. High power IR LED driver circuit using NMOS for fast rise and fall switching times

Low-side and high-side MOSFET drives are configurations utilized to control MOSFETs in power electronic circuits, enabling the switching of loads on and off. The selection between low-side and high-side configurations is contingent upon the circuit topology and the requirements of the application. In this study, a low-side MOSFET drive was chosen due to its simplicity and ease of implementation, as only the gate voltage needs to be driven to ground potential, facilitating control using low-level signals. Furthermore, a low-side driver does not necessitate complex circuitry to regulate the gate voltage above the source potential, wherein a bootstrap circuit may not be requisite. [9], [10]. In contrast, for a high-side driver, to activate a high-side N-channel MOSFET, the gate voltage must be elevated above the source voltage (which is at the supply level). This typically necessitates a gate driver capable of providing a voltage higher than the supply voltage or utilizing a P-channel MOSFET, which activates when the gate voltage is lower than the source voltage. High-side switches may be more susceptible to voltage spikes [11], [12], [13]. In this work, a low side driver configuration was used since it is more suitable for the SAT circuit application. A low side driver circuit to maximize the power output of the IR led is shown in Fig 7. The NMOS IRFZ44N is a specific type of N-channel MOSFET that is commonly used in power applications due to its ability to handle high voltages and currents. Some important parameters of IRFZ44N to consider are as follows: V_{DS} (Drain-Source Voltage) is typically rated at 55V, I_D (Continuous Drain Current) is up to 49A under certain conditions (with appropriate heatsinking), V_T (Gate-Source Threshold Voltage) is between 2V and 4V, $R_{DS(\text{on})}$ (On-Resistance) is typically around 0.025Ω at $V_{GS} = 10$V, power dissipation (P_D) is rated for a maximum of around 94W, gate charge (Q_g) is approximately 67nC. According [11], the characteristic of the rise and the fall transient time for high power IR emitter can be expressed as:

$$t_r = \frac{1.49}{\sqrt{k_{\text{LED}} I_p}} \quad (10)$$

$$t_r = \frac{2.11}{\sqrt{k_{\text{LED}} I_p}} \quad (11)$$

where t_r and t_f are the rise time and the fall time, respectively, k_{LED} denotes the constant of LED characteristic parameter, and I_p is the magnitude of the pulsed current passing the emitter. It can be observed from the equations (10) and (11) describing the intrinsic behaviour of the emitter, that the fall time is slower that the rise time.

A pulse shaping circuit is necessary to compensate for the intrinsic behaviour of the emitter and to maximize power output. A series of R_3 and L_1 is referred to as the sweep-out circuit. High-current IR emitters require a long time delay to switch the current from high to low levels. Therefore, the implementation of a sweep-out circuit aims to improve the falling time. A parallel circuit of R_2 and C_1 is termed a peaking circuit. A peaking circuit is utilized to

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reduce the optical rise time of the IR. The resistance value of R_2 limits the IR emitter current. In addition to the pulse shaping circuit, a Schottky diode functions as a flyback diode, which can rapidly discharge the energy stored by the inductive load during the transition from on state to off state. The component values of the pulse shaping circuit require calibration to achieve the desired pulse and duration. Consequently, the precise values may need to be determined through experimental methods or simulation techniques.

Simulation results of a low-side MOSFET driver in Fig 7 are shown in Fig 8-Fig 10. The configuration in Fig 8 yields the most satisfactory pulse shape, where the rise time and fall time were rapid without any ringing or oscillation in each switch state. It is noteworthy that, during the OFF state, the IR emitter was reverse biased with 0.1V . This reverse bias voltage is significantly lower than the breakdown voltage of the IR emitter. Utilizing the configuration described in Fig 9, the fall delay time of the IR emitter voltage was the longest among the three configurations. The substantial sweep-out resistance rendered the fall delay more pronounced.

Increasing the capacitance value C_1 of peaking circuit would improve the rise time duration as shown in the simulation result in Fig 10. However, bigger capacitance value of C_1 is more susceptible to voltage spike of V_{IR}.

A complete design of the SAT circuit was made using the best pulse shaping circuit configuration of the low-side MOSFET driver. To drive the gate of IRFZ44N, a non-inverting push-pull transistor circuit was added, as shown in Fig 11.

The microcontroller (MCU), which is the source of the gating signal, generally has a low current capability below 0.1A and cannot directly drive power devices. Assuming that the input capacitance of MOSFET is 5nF and that the output impedance of I/O port of the microcontroller is 500Ω, the time-constant t is given as

$$t = CR = 5 \times 10^{-9} \times 500 = 2.5\mu s \tag{12}$$

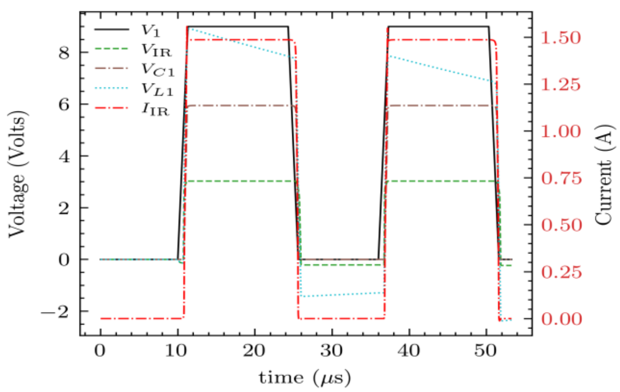

Fig 8. $R_2 = 4\Omega$, $C_1 = $ 10nF, $R_3 = 100\Omega$, $L_1 = $ 10mH

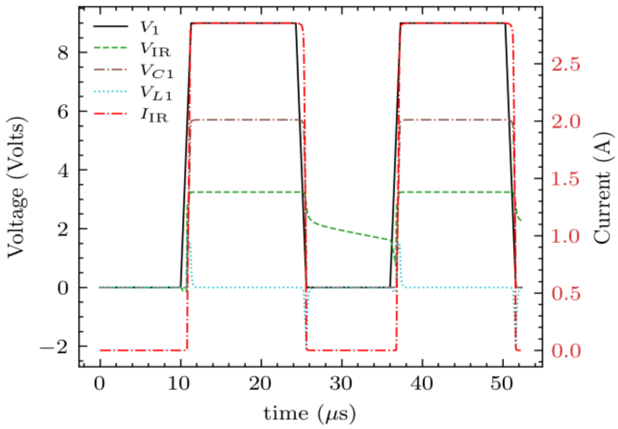

Fig 9. $R_2 = 4\Omega$, $C_1 = $ 10nF, $R_3 = $ 100kΩ, $L_1 = $ 10mH

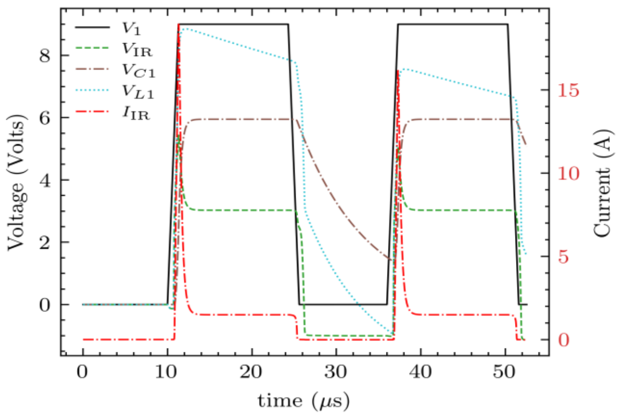

Fig 10. $R_2 = 4\Omega$, $C_1 = 2\mu F$, $R_3 = 10k\Omega$, $L_1 = 10mH$

The gate turns on and off at a very slow rate, resulting in a large switching loss. Driving at high speed is also one of the roles of the gate driver in order to drive power devices optimally. Therefore, adding a non-inverting push pull transistor amplifier is necessary.

The MCU send out the 38KHz modulated data signal of PID to one of the GPIO pin. This signal drive transistor Q_1 through the Q_1 emitter. Since the Q_1 base is supplied with a constant 3.3V, a low level pulse would activate the Q_1, and the output from the collector would also in low level state (non-inverting drive). This output drive the base of the push pull transistor circuit. When the logic level of the Q_1 is high, the Q_2 is driven, the MOSFET gate is charged through R_1. Resistor R_6 was added to reduce the gate-source voltage to 0V when the input signal is open-circuited. Without R_6, a false activation of M_1 may occur. This phenomenon is called the parasitic turn-on (self-turn-on) phenomenon caused by MOSFET drain-gate capacitance. The purposes of the gate resistor R_1 include suppression of inrush current and a reduction in output ringing. A large gate resistor decreases the switching speed of a MOSFET. This results in an increase in power loss, a reduction in performance and potential heat issues. Conversely, a small gate resistor increases the switching speed of a MOSFET, which makes it susceptible to voltage surge and oscillation and therefore to device failure and damage. It is therefore important to optimize the MOSFET

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switching speed by adjusting the gate resistor value. The gate rise time t_G and the gate resistor value $R_G = R_1$ have the following relationships

$$I_G = \frac{Q_G}{t_G} \quad (13)$$

$$R_G = \frac{V_{GS}}{I_G} \quad (14)$$

Where Q_G is the gate charge. The diode 1N4148 was used to bypass the R_1 during the switch off state. In the off state, the gate is discharged, the gate current flows through the diode 1N4148, and sinks to ground through Q_3. The diode 1N4148 helps to reduce the fall time delay of the gate discharging.

A simulation of the SAT IR emitter driver circuit was conducted using LTSPICE. The circuit transient performances validation was focused on: the IR emitter voltage drop V_{IR} and current I_{IR}, the pulse current I_{pulse}, push pull output voltage V_{pushpull}, gate voltage V_G and the gate resistor voltage V_{R1}.

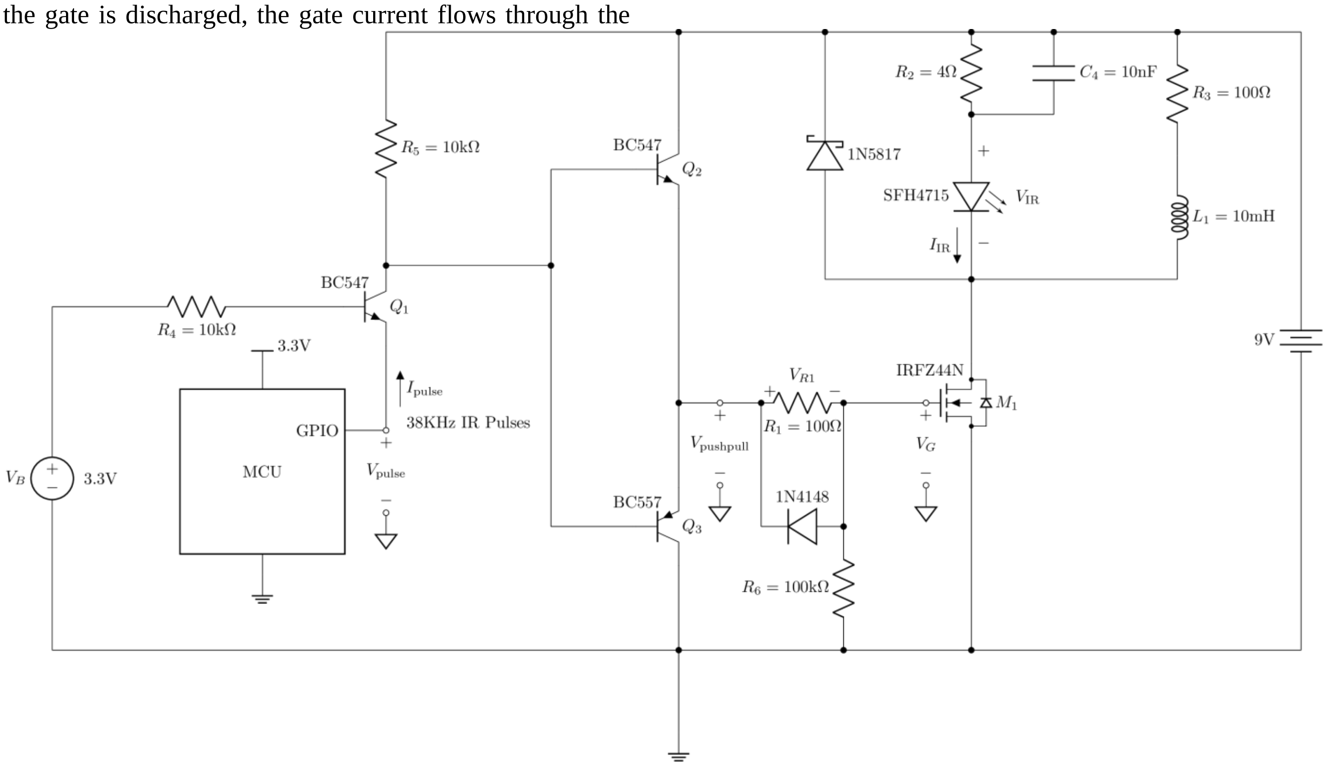

Fig 11. SAT IR emitter driver circuit

The transient response of current source and sink of the MCU GPIO is shown in Fig 13. It shows that a very short time spike of the I_{pulse} current was occurred. The maximum amplitude was $\pm$5mA, which is still safe for the MCU to source and sink the current. A quick gate charge and discharge signal can be seen in Fig 14. The gate voltage V_G and the push pull output voltage are almost similar, with small time discrepancy during the rise time.

The gate resistor was successfully doing the job to shortening the rise time period. The diode 1N4148 was also functioning properly to decrease the fall time delay. It can also be seen from the shape of the V_{R1} transient response. A quick spikes during the charge and discharge of the MOSFET gate were observed. During the discharge, a small negative voltage drop of V_{R1} was from the forward bias voltage of the diode 1N4148.

Fig 12 shows the transient responses of V_{IR}, I_{IR} and V_{pulse}. The modulated signal V_{pulse} with the frequency of 38KHz is the input signal to the SAT circuit, with an amplitude of 3.3V. The SAT output voltage V_{IR} was pulsating with the same frequency of the input signal with a very small shifting period (minimal rise and fall time delays), and with amplitude of 3V. The current flow I_{IR} reached 1.5A flat during the on period. In this case the power output of 4.5W was achieved. For a higher power output specification or requirement, lowering the value of the R_2 is needed. An adjustment of the pulse shaping components values is also required.

Fig 13 depicts the transient response of current source and sink of the MCU GPIO. Short time spikes of $\pm$4mA have been observed, which were still in the safety region. Usually the maximum current source and sink allowed are within the range of $\pm$10mA.

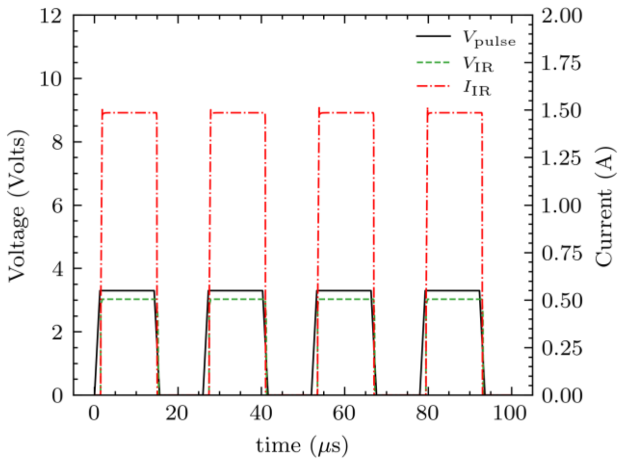

Fig 12. Transient responses of V_{IR}, I_{IR}, V_{pulse}

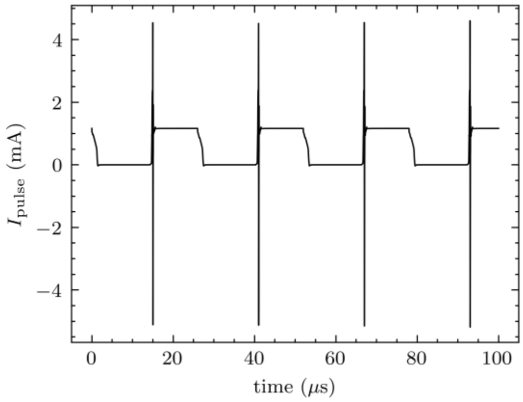

Fig 13. Transient response of current source and sink of the MCU GPIO

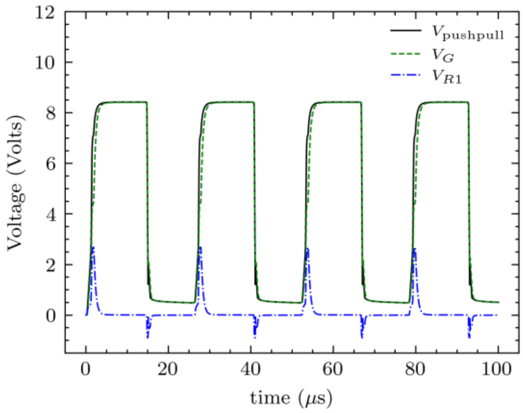

Fig 14. Transient responses of the gate voltage V_G and the V_{R1}

Fig 14 illustrates the transient response of the V_G and the V_{R1}. It is evident that the push-pull output voltage was utilized almost to its full extent in driving the MOSFET gate, as the dropping voltage was minimal. The positive short spikes were attributable to the charging time of the gate-source capacitance. During the discharge process, the discharging current passed through the 1N4148 diode, resulting in the negative spike of ± 0.7V of R_1 voltage. The gate driver circuit performed as anticipated.

5 CONCLUSION

The proposed circuit design of an infrared emitter driver circuit of SAT for MILES application has been examined. Practical design considerations of the driver development have also been presented. The primary objective of the circuit design is to maximize the IR emitter power output, given a high switching frequency of 38KHz (NEC standard IR communication protocol frequency) modulated signal provided by a low-level voltage MCU GPIO. The simulation results demonstrate that the pulse shaping circuit performed as anticipated. The driver is capable of producing satisfactory pulse shapes of the voltage and current of the IR emitter, wherein a high-power output of 4.5W can be achieved. The circuit component values can be adjusted to meet higher power output requirements.

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7. AUTHOR CONTRIBUTIONS

All the authors have been contributed equally to finish this work.

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