

Optical Morse Code Communication Using an Arduino-Controlled LED and a Photoresistor Receiver

Aikun Wang and Olive Patton

Department of Physics, Emory University, Atlanta, GA, USA

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We designed and tested a simple optical communication system inspired by the Morse-code signaling scene in the film *Infernal Affairs*. In the film, an undercover agent secretly transmits information through Morse code; in our implementation, the human tapping signal is replaced by an Arduino-controlled light-emitting diode (LED), and the receiver is a photoresistor voltage-divider circuit. The LED was driven using pulse-width modulation (PWM) on Arduino digital pin 9, with three optical states: bright LED for a dash, medium LED for a dot, and LED off for gaps. A photoresistor circuit connected to analog input A0 converted the received optical signal into a voltage. Calibration showed three clearly separated voltage levels: approximately 1.632 V for the bright LED state, 2.131 V for the medium LED state, and 4.555 V for the LED-off state. To reduce ambient classroom light, the transmitter and receiver were covered with a cardboard enclosure. We successfully transmitted and visually decoded the messages “HELLO” and “DR BRODY” from voltage-versus-time data. This project demonstrates how a basic circuit can be used as a functional optical communication system by combining voltage division, light-dependent resistance, PWM control, and digital signal encoding.

I. INTRODUCTION

Morse code is a classic example of symbolic communication. A message is encoded as a sequence of short and long signals, traditionally called dots and dashes. Although Morse code is historically associated with telegraphs, radio, and flashing lamps, the essential idea is more general: information can be transmitted whenever a sender and receiver agree on how to interpret a sequence of physical signals.

The motivation for this project came from the Hong Kong film *Infernal Affairs*. In one scene, an undercover police officer secretly communicates information to the police using Morse code by tapping his hand on a window ledge. This scene inspired us to build a more electronic and automated version of the same idea. Instead of a hand tapping a window, our transmitter uses an LED. Instead of a person visually reading the signal, our receiver uses a photoresistor circuit that converts changes in light intensity into measurable voltage changes.

The goal of the project was to construct a proof-of-concept optical Morse code communication system. The Arduino converts ordinary text into Morse code and then controls the LED brightness to transmit the coded message. The photoresistor receiver measures the changing light intensity as a voltage signal. By plotting the received voltage as a function of time, the original Morse code can be reconstructed.

This project combines several topics from introductory electronics and experimental physics: Ohm’s law, voltage dividers, analog voltage measurement, digital output, pulse-width modulation, sensor calibration, and signal interpretation.

II. PHYSICAL PRINCIPLES

A. Photoresistor voltage divider

A photoresistor, also called a light-dependent resistor, changes its resistance in response to light intensity. When the incident light intensity increases, the resistance of the photoresistor decreases. When the light intensity decreases, its resistance increases.

In our receiver circuit, the photoresistor was placed in series with a fixed resistor to form a voltage divider. The Arduino measured the voltage at the midpoint of the divider using analog input A0. The ideal voltage-divider relation is

$$V_{\text{out}} = V_{\text{in}} \frac{R_{\text{photo}}}{R_{\text{fixed}} + R_{\text{photo}}}, \quad (1)$$

where R_{photo} is the resistance of the photoresistor, R_{fixed} is the fixed resistance, and $V_{\text{in}} = 5 \text{ V}$ is the Arduino supply voltage.

In our wiring configuration, brighter LED illumination reduced R_{photo} , which lowered the measured output voltage. Therefore,

$$\text{brighter light} \Rightarrow R_{\text{photo}} \downarrow \Rightarrow V_{\text{out}} \downarrow. \quad (2)$$

As a result, the received voltage was lowest when the LED was brightest, intermediate when the LED was at medium brightness, and highest when the LED was off.

B. Pulse-width modulation and LED brightness

The LED was controlled by Arduino digital pin 9, which supports pulse-width modulation (PWM). PWM

does not produce a true continuous analog voltage. Instead, the output rapidly switches between 0 V and 5 V. By changing the duty cycle, defined as the fraction of each cycle during which the output remains on, the Arduino changes the average power delivered to the LED. This changes the apparent brightness of the LED.

In our experiment, three PWM states were used:

This encoding differs slightly from traditional Morse code. In standard Morse code, dots and dashes are often distinguished by duration. In our system, dots and dashes were primarily distinguished by light intensity, while their durations were kept the same. This choice made the signal easier to identify visually from the voltage-time graphs, because dots and dashes appeared as different voltage levels.

III. EXPERIMENTAL DESIGN

A. Circuit construction

The system consisted of two main parts: an optical transmitter and an optical receiver. The transmitter circuit used an LED in series with a current-limiting resistor. The LED was connected to Arduino pin 9, allowing its brightness to be controlled by PWM.

The receiver circuit consisted of a photoresistor and a fixed resistor connected as a voltage divider. The output voltage of the divider was connected to analog input A0. The Arduino repeatedly read this voltage while the LED transmitted the Morse code sequence.

Because the classroom environment was brightly lit, ambient light introduced a strong background signal. To reduce this effect, we placed a cardboard cover over the LED and photoresistor. This created a darker local environment and made the LED-induced voltage changes more visible.

B. Timing protocol

The transmitted Morse code signal used fixed timing intervals. Each dot or dash was held for 2 s. The gap between symbols was 1 s, the gap between letters was 1.5 s, and the gap between words was 3 s. The analog input was sampled every 0.5 s. These values are summarized in Table II.

The long timing intervals made the signal easy to observe and decode manually. Since this project was

TABLE I. Encoding scheme used for the optical Morse code transmitter.

LED state	Morse meaning	Expected receiver voltage
Bright LED	Dash, -	Lowest voltage
Medium LED	Dot, .	Intermediate voltage
LED off	Gap/space	Highest voltage

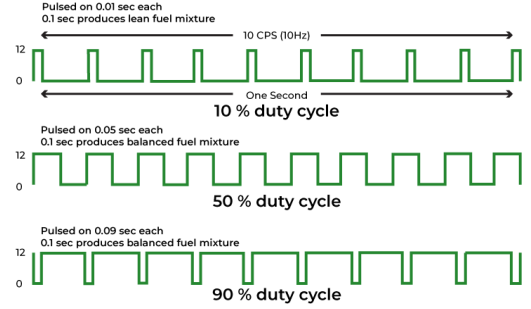


FIG. 1. Illustration of PWM duty cycle. A larger duty cycle corresponds to a larger fraction of time spent at 5 V, producing greater average LED brightness.

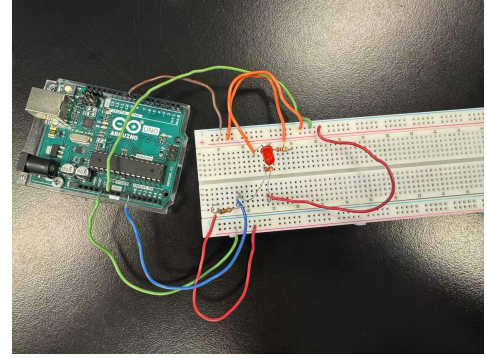


FIG. 2. Photograph of the Arduino, breadboard, LED transmitter, and photoresistor receiver. The LED sends the optical Morse code signal, while the photoresistor voltage divider measures the received light intensity.

a proof-of-concept demonstration, clarity and reliability were prioritized over transmission speed.

IV. CALIBRATION

Before transmitting a message, the system was calibrated by measuring the photoresistor voltage under three controlled LED states: bright, medium, and off. The measured calibration values are shown in Table III.

The measurements confirmed that the three states were clearly distinguishable. The bright LED produced the lowest voltage because strong illumination reduced the photoresistor resistance. The LED-off state produced the highest voltage because the photoresistor was mostly in the dark and therefore had a larger resistance.

The calibration established the key inequality

$$V_{\text{dash}} < V_{\text{dot}} < V_{\text{off}}. \quad (3)$$

This separation allowed dots, dashes, and gaps to be identified from the voltage-versus-time plots.

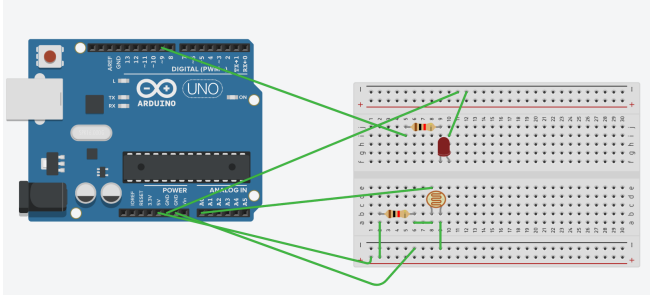


FIG. 3. Circuit diagram of the optical communication system. The LED is controlled by Arduino digital pin 9, and the photoresistor voltage divider is measured through analog input A0.

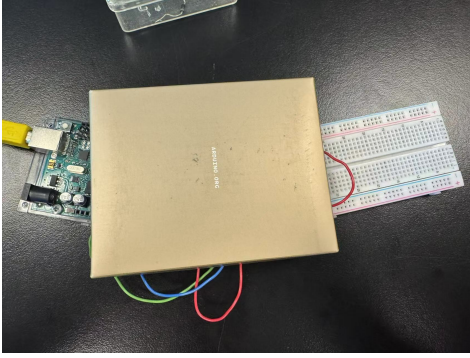


FIG. 4. Cardboard cover used to reduce ambient classroom light. The cover improved the voltage separation between the bright, medium, and off optical states.

V. SERIAL MONITOR OUTPUT

The Arduino Serial Monitor displayed both the encoded Morse sequence and the measured voltage values. A typical shortened output during the transmission of “HELLO” is shown below.

Listing 1. Shortened example of Serial Monitor output during optical Morse code transmission.

```
System ready.

=== CALIBRATION START ===
Bright LED Intensity: 1.632 V
Medium LED Intensity: 2.131 V
Off LED voltage: 4.555 V
=== CALIBRATION END ===

=== TRANSMITTING ===
Input text: HELLO
H -> ....
E -> .
L -> .-..
L -> .-..
O -> ---

57:47.5 -> H -> ....
57:47.6 -> 4.482
57:48.0 -> 2.268
57:48.5 -> 2.649
```

TABLE II. Timing parameters used during transmission and data collection.

Parameter	Value
Symbol duration	2000 ms
Gap between symbols	1000 ms
Gap between letters	1500 ms
Gap between words	3000 ms
Sampling interval	0.5 s

```
57:49.0 -> 2.190
57:50.0 -> 4.531
...
58:01.0 -> E -> .
58:01.0 -> 4.492
58:01.5 -> 2.620
58:02.1 -> 2.229
...
=== TRANSMISSION DONE ===
```

Values near 4.5 V correspond to the LED-off state and represent gaps. Values near 2.1 V–2.6 V correspond to the medium LED state and represent dots. Lower voltage values correspond to the bright LED state and represent dashes. Thus, the Serial Monitor output contains the same information that appears in the voltage-time plots.

VI. RESULTS

A. Transmission of “HELLO”

The first transmitted message was “HELLO”. In Morse code,

$$\text{HELLO} = \dots \quad . \quad . - \dots \quad . - \dots \quad - - - \quad . \quad (4)$$

The measured voltage as a function of time is shown in Fig. 5. Medium voltage dips correspond to dots, deeper voltage dips correspond to dashes, and high-voltage regions correspond to LED-off gaps.

From Fig. 5, the first repeated sequence of medium dips corresponds to “...”, or H. A single medium dip corresponds to E. The pattern “.-.” appears twice, corresponding to the two L’s. Finally, the three deeper dips correspond to “—”, or O. Therefore, the voltage graph reconstructs

$$\dots \quad . \quad . - \dots \quad . - \dots \quad - - - \Rightarrow \text{HELLO}. \quad (5)$$

TABLE III. Measured calibration voltages for the three optical states.

LED state	Morse meaning	Measured voltage
Bright LED	Dash	1.632 V
Medium LED	Dot	2.131 V
LED off	Gap/space	4.555 V

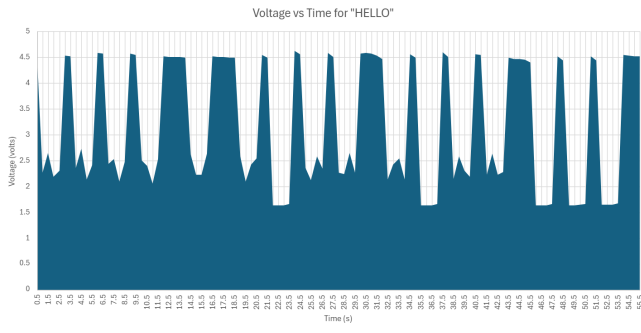


FIG. 5. Voltage versus time for the transmitted message “HELLO”. Medium dips correspond to dots, deeper dips correspond to dashes, and high-voltage regions correspond to gaps.

This first test confirmed that the LED-photoresistor system could transmit and preserve a recognizable message.

B. Transmission of “DR BRODY”

After successfully transmitting the test message “HELLO”, we designed a more playful and movie-inspired second trial. Imagine an undercover agent who cannot speak openly. As in the Morse-code scene from *Infernal Affairs*, the message must be transmitted silently through a coded signal. However, instead of tapping on a window ledge, the agent uses an LED as an optical transmitter.

The secret message is the code name of the agent to be contacted: “DR BRODY”. If the police station can correctly receive and decode this optical signal, the mission can continue. In Morse code, the message is

$$\text{DR BRODY} = -.. \ .-. \ / \ -... \ .-. \ ---- \ -.. \ -.- \ (6)$$

The measured signal is shown in Fig. 6. The longer high-voltage region near the middle represents the word gap between “DR” and “BRODY”.

The graph can be read like a secret optical fingerprint. The first symbol group, $-..$, decodes to D, and the next group, $.-.$, decodes to R. After the longer off-state gap, the second word begins: $-...$ for B, $.-.$ for R, $----$ for O, $-..$ for D, and $-.-$ for Y. Therefore, the measured voltage signal reconstructs

$$-.. \ .-. \ / \ -... \ .-. \ ---- \ -.. \ -.- \Rightarrow \text{DR BRODY} \quad (7)$$

This second test shows that the system can transmit a longer, mission-style message with multiple letters and a clear word gap. In the language of the film-inspired scenario, the LED-photoresistor system successfully delivered the code name without making a sound.

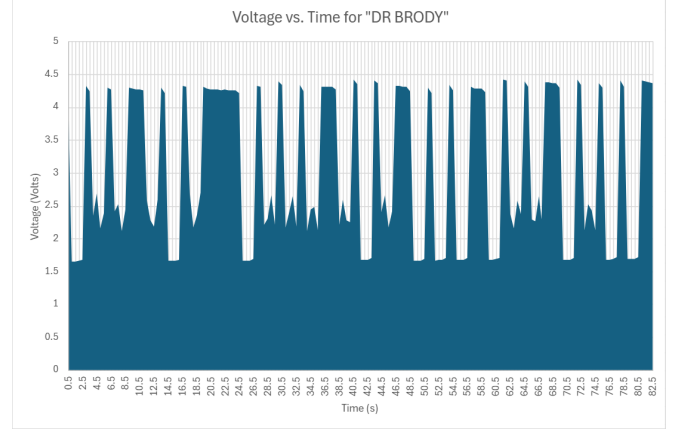


FIG. 6. Voltage versus time for the transmitted message “DR BRODY”. Medium voltage dips correspond to dots, deeper voltage dips correspond to dashes, and the longer high-voltage gap near the middle represents the word gap between “DR” and “BRODY”.

VII. DISCUSSION

The system worked because the photoresistor voltage divider converted variations in light intensity into measurable voltage changes. The Arduino then provided both signal control and data acquisition. The calibration values showed that the three optical states were sufficiently separated, which was the central requirement for successful decoding.

A distinctive feature of this design is that dots and dashes were separated by intensity rather than duration. In traditional Morse code, a dash is usually longer than a dot. In our design, dots and dashes had the same duration but different LED brightness levels. This made manual decoding from voltage plots easier because each symbol corresponded to a different voltage level. The trade-off is that the receiver must distinguish brightness levels accurately. If the ambient light is too strong, or if the LED is not well aligned with the photoresistor, the dot and dash voltage levels may overlap.

The cardboard cover was therefore important. Without it, classroom lighting would add a large background signal to the photoresistor and reduce the contrast between the LED states. With the cover, the LED became the dominant light source, and the voltage separation between states improved.

There were also several limitations. First, the transmission speed was slow because the symbol duration was 2s. This made the signal easy to observe, but it would not be efficient for practical communication. Second, the voltage thresholds were manually calibrated. If the lighting conditions changed, new thresholds would be needed. Third, the system depended on the physical alignment between the LED and the photoresistor. If the LED was moved farther away or pointed in a different direction, the received signal would weaken.

Future versions could improve the receiver by using automatic threshold calibration before each transmission. The system could also transmit faster by using shorter symbol durations and a faster optical detector. A photodiode or phototransistor would likely provide faster response and better sensitivity than a photoresistor. More advanced versions could also use multiple LED colors or multiple intensity levels to encode more information per symbol.

VIII. CONCLUSION

We built and tested an Arduino-based optical Morse code communication system using an LED transmitter and a photoresistor receiver. The project was inspired by the Morse-code communication scene in *Infernal Affairs*, but implemented as an electronic optical communication system.

Calibration showed three clearly separated voltage states: the bright LED state produced the lowest voltage, the medium LED state produced an intermediate volt-

age, and the LED-off state produced the highest voltage. The voltage-versus-time graphs for “HELLO” and “DR BRODY” contained recognizable Morse code patterns and allowed the original messages to be reconstructed.

Overall, this project transformed a simple circuit into a functional communication device. It combined physics, electronics, coding, and a film-inspired idea into a working optical Morse code transmitter and receiver.

Appendix A: Morse Code Table

TABLE IV. Morse code table for letters used in the project.

A	.-	B	-...	C	-.-.	D	-..
E	.	F	..-.	G	-.	H	
I	..	J	.—	K	-.-	L	.-..
M	—	N	-.	O	—	P	.-.
Q	-.-	R	.-.	S	...	T	-
U	..-	V	...-	W	.-	X	-.-
Y	-.-	Z	-..				

[1] Arduino Documentation, “analogWrite()”, Arduino Reference. Available at: <https://www.arduino.cc/reference/en/language/functions/analog-io/analogwrite/>

[2] International Telecommunication Union, “International Morse Code,” ITU Recommendation M.1677-1.

[3] Andrew Lau and Alan Mak, *Infernal Affairs*, Media Asia Films, 2002.