



runlinc Project 8 C2: The Binary System (E32W Version)

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Introduction

What is the binary system?

The binary system is when a system consists of a sequence of only two states. And it can be represented in the STEM field as a numerical system which uses only 2 numbers, 0 and 1. In a more technical term, it is a numerical system which uses base 2. An example of a binary number is 11110100. Furthermore, a digit in binary is called a binary digit and is often shortened to a bit. So, from the example 11110100, it has 8 digits, therefore say that the binary number is 8 bits long. And when you have 8 bits altogether, this is known as a byte. Also, when reading a binary number, read each digit individually.

Why do we use the binary system?

In electrical and computer fields, hardware has at least 2 primary methods to process electrical signals. One is analog and the other is digital. Analog uses the smooth and continuous form of an electrical signal to function. Whereas in the digital method, any information conveyed by an analog electric signal will be broken down into a sequence of binary states of electricity being on or off. The binary on and off means we can use binary mathematics to design hardware for function-specific outputs.

The particularity of the digital system means we can store binary data by keeping the on and off state for a data in a particular module for later use and then use a binary arithmetic module to manipulate the stored data. It is more difficult to store information of an analog system and more likely not able to use the stored information for further processing. This is a critical principle which allows us to create logic circuits and therefore microchips and computers.

Additionally, since an analog system uses the original form of an electrical signal, electromagnetic effects from other devices can easily affect the analog system as it will affect the analog system's signal's amplitude. Whereas in the digital system, one can be certain a signal is either on or off at a certain amplitude threshold, this means that electromagnetic effects from other devices are less likely to affect the digital system. Therefore, combining this knowledge with the ability for further processing, many newer electronics will use the digital method and thus, it is necessary to understand the binary system.

However, it should be noted that digital signals cannot convert a continuous (infinite) signal into a binary form and not taking up too many digits to store the signal. This means a binary number with fewer digits (bits) is less precise. And it should also be noted that the digital form can also be converted back to analogue form, but it will be affected by the number of bits that the digital signal contains.

How does binary numeral system work?

The binary numeral system works similar to the commonly used decimal system (0 to 9). To count in binary, in a digit, we count from 0 to 1. At 1, if we need to count one more, we start from 0 but carry 1 to the left. If we are counting in reverse, we count from 1 to 0, and to count further, we borrow 1 from the left. You can use usual arithmetic methods on binary numbers the same way, see the following figure. Additionally, you can convert between binary and decimal, the following link is explain the details further,

https://www.electronics-tutorials.ws/binary/bin_2.html

Addition	Subtraction	Multiplication	Division
$0 + 0 = 0$ $1 + 0 = 1$ $0 + 1 = 1$ $1 + 1 = 0$ and carry 1	$0 - 0 = 0$ $1 - 0 = 1$ $0 - 1 = 1$ and carry 1 $1 - 1 = 0$	$0 \times 0 = 0$ $1 \times 0 = 0$ $0 \times 1 = 0$ $1 \times 1 = 1$	$0 \div 1 = 0$ $1 \div 0 = \text{not defined}$ $0 \div 0 = 0$ $1 \div 1 = 1$
Example: $\begin{array}{r} 11 \\ 11 \\ \hline 110 \end{array}$ Here, $1+1$ (right most) = 0 and its carry 1 is added to left columns as $1+1+1=11$ Hence, $11+11=110$	Example: $\begin{array}{r} 10 \\ 01 \\ \hline 01 \end{array}$ Here, $0-1$ (right most) = 1 because we take carry 2 from left column, and left remains 0. Hence, $10-01=01$	Example: $\begin{array}{r} 11 \\ 10 \\ \hline 00 \\ 11 \times \\ \hline 110 \end{array}$ Tryout: (a) 1001×11 (b) 1100×101 (c) 1111×110 (d) 1010×1001	Example: $\begin{array}{r} 11 \overline{) 110} \\ \underline{11} \\ 00 \\ \underline{ 00} \\ 00 \end{array}$ Try out: (a) $111 \div 11$ (b) $1100 \div 11$ (c) $1001 \div 11$ (d) $1011 \div 100$ (e) $1111 \div 1011$

Figure 1 Binary Arithmetic Methods.

¹ <https://www.sciencehq.com/wp-content/uploads/Binary-Arithmetic.jpg>

Furthermore, in mathematics, there is a field called Boolean algebra where binary states can be manipulated using logic. It is a simple but powerful mathematic model that helps us design hardware. By using Boolean algebra we can take some particular input and then logically state the output. Then apply this to an electric circuit which once we apply this concept, is called a logic circuit. In this field, 1 and 0 can be thought as true or false, respectively. Additionally, on and off, respectively. The following figure will show the fundamental logic needed for Boolean algebra. Watch the following link to understand more about Boolean algebra: <https://www.youtube.com/watch?v=gl-qXk7XojA>



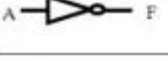


Name	Graphic Symbol	Boolean Algebra	Truth Table															
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1	1	0																

Figure 2 Fundamental Boolean Logics

Summary

We hope that this brief introduction has allowed you to briefly understand what is the binary system is, why we use it in the STEM field, especially in the electrical and computer field, and that you learned how the binary system can be manipulated using arithmetic and Boolean algebra.

runlinc Background

runlinc is a web page inside a Wi-Fi chip. The programming is done inside the browsers compare to programming inside a chip. The runlinc web page inside the Wi-Fi chip will command the microchips to do sensing, control, data logging Internet of Things (IoT). It can predict and command

² <https://maecellesther.files.wordpress.com/2017/10/boolean.jpg?w=487&h=365>

A Simple Application: Binary Representation

Problem

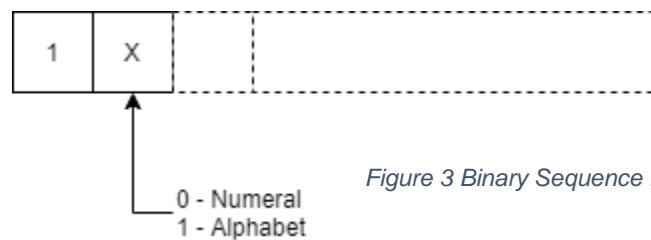
Think of the trapped miners application in the telecommunication introduction. We used a programmable microchip on the surface which is connected to the light in the cave visible to the miners to send flashes of on and off of the light to the trapped miners and counting each flash for the number that we need. But what if instead of this situation, we need to convey to the trapped miner with other types of information? In the new situation for the trapped miner, they will need both alphabet and numeral information to disable the explosives.

Ideas

How can we use binary to represent more complex information? Computer uses binary sequence to function, so how can we see latin characters? Think of morse code like the previous trapped miner application, how did people communicate with one another with morse code. How should we signify that it is an alphabet or numeral?

Plan

We will build upon the previous trapped miner setup. We will first need to decipher if the following character for the combination is a number or an alphabet. We should use the first two digit of the binary sequence to decipher if the rest of the sequence is a number or an alphabet. The first digit will always be On, to allow the miner know that the sequence has started. The second digit will be Off to signify that the rest of the sequence is a number. Whereas, when the second is on, the rest of the sequence is an alphabet.



But here is the problem, if we turn off the light entirely during the off digit, the miners will not know if the sequence is for the next code and also will have a hard time, finding the position of the bits in the sequence. Therefore, we will set that a long flash is an On and a very short flash is an Off. And we will be using decimal to binary and binary to decimal conversion, in order to shorten the on and off flashing time.

If you still haven't thought of a way to encode alphabets. No worries. It is simple to encode alphabet into binary. We will use a method which computers store and use alphabets. We simply encode the respective alphabets in alphabetical order with their respective numerical number.

Part A: Design the Circuit on runlinc

Note: Refer to runlinc **Wi-Fi Setup Guide** document to connect to runlinc

Use the left side of the runlinc web page to construct an input/output (I/O).

In our circuit design,

- ❖ D5->DIGITAL_OUT :
- ❖ D18->DIGITAL_OUT : Lightbulb
- ❖ D19->DIGITAL_OUT :

D5	DIGITAL_OUT		OFF
D12	DISABLED		
D13	DISABLED		
D14	DISABLED		
D15	DISABLED		
RX2	DISABLED		
TX2	DISABLED		
D18	DIGITAL_OUT	Lightbulb	OFF
D19	DIGITAL_OUT		OFF

Figure 4 Expected I/O Configuration.

Part B: Build the Circuit

Use the STEMSEL E32 board to connect the hardware. For this project we are using both the left and right I/O ports, with **negative port (-ve)** on the outer side, **positive port (+ve)** on the middle and **signal port (s)** on the inner side (as shown below).

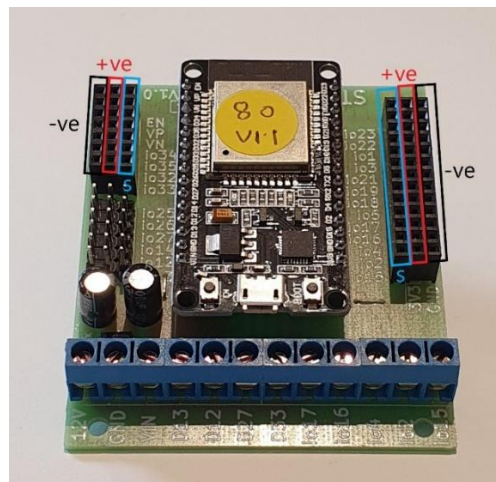


Figure 5: E32W

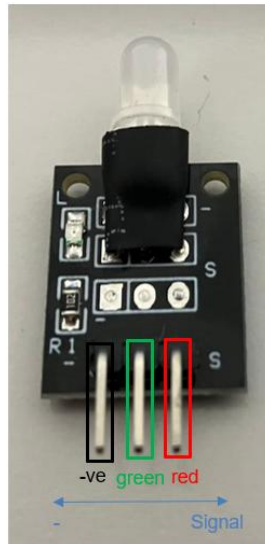


Figure 6: I/O parts with negative and signal pins indicate

Wiring Instructions

Plug in the LED to signal ports io5, io18 and io19 on the E32W board with the “red” pin on the light that goes into io5, corresponding to the port D5.



Figure 7: Circuit board connection with I/O parts (side view)

Part C: Program the Circuit

HTML

We will first set up a simple HTML page to show what the miners will see, such that we can confirm it is the message we want to send. We will use a circle to mimic the light bulb. And lets remind us what the circle is the lightbulb with a header.

```
<h1>This is what the miner will see.</h1>
<svg height="100" width="100">
  <circle id="circle" cx="50" cy="50" r="40" stroke="black" stroke-width="3" fill="white" />
</svg>
```

JavaScript

We will write several function in JavaScript which will help us send information to the miners.

1. We will write an on function which has long turn on time and a short turn off time.

```
async function on(){
  turnOn( Lightbulb );
  document.getElementById("circle").style.fill="gold";
  await mSec( 1500 );
  turnOff( Lightbulb );
  document.getElementById("circle").style.fill="white";
  await mSec( 500 );
  return Promise.resolve();
}
```

2. Then a off function that has the opposite light behavior.

```
async function off(){
  turnOn( Lightbulb );
  document.getElementById("circle").style.fill="gold";
  await mSec( 500 );
  turnOff( Lightbulb );
  document.getElementById("circle").style.fill="white";
  await mSec( 1500 );
  return Promise.resolve();
}
```

3. Then we will write a blink function that will utilize the on and off function. For the blink function, we will first initialize with an on. Then check if this blink message is a number or an alphabet. Then we will turn the value into binary message and send the message to the miners by utilizing decimal to binary conversion. Numerals will utilize 4 bits because 4 bits go upto 16 unique values where as 3 bits go up to 8 unique values, so $i = 3$. And alphabet will utilize 5 bits since it can provide 32 unique values.

```
async function blink(isNumber, value){
  await on();
  //Check if it is number of alphabet.
  if( isNumber ){
    await on();
  }else{
    await off();
  }
  let v = value;
  let i = 3; // Set i = 3 or 4 depending on if it is a number or an alphabet.
```

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```
if( !isNumber ){
  i = 4;
}
// Decimal to binary conversion readable by the miners.
for( i ; i>=0; i--){
  if( (v>>i) & 1 == 1){
    await on();
  }else{
    await off();
  }
}
return Promise.resolve();
}
```

JavaScript Loop

The JavaScript Loop will be used to implement the message to the miners. Between each blink message will need a 3 second delay, and the last message will have a 10 second delay afterwards.

```
await blink(true, 3);           //Code: 3
await mSec( 3000 );
await blink(false, 26);        //Code: Z
await mSec( 3000 );
await blink(false, 1);         //Code: A
await mSec( 3000 );
await blink(true, 8);          //Code: 8
await mSec( 10000 );
```


Expected runlinc and web page:

runlinc 2.3.1

File: Load File, Save

Board: Send, Get

Board IP: http://192.168.0.55

ESP32

PORT	CONFIGURATION	NAME	STATUS
D2	DISABLED		
D4	DISABLED		
D5	DIGITAL_OUT		OFF
D12	DISABLED		
D13	DISABLED		
D14	DISABLED		
D15	DISABLED		
RX2	DISABLED		
TX2	DISABLED		
D18	DIGITAL_OUT	Lightbulb	OFF
D19	DIGITAL_OUT		OFF
D21	DISABLED		
D22	DISABLED		
D23	DISABLED		
D25	DISABLED		
D26	DISABLED		
D27	DISABLED		
D32	DISABLED		
D33	DISABLED		

CSS

```
<h1>This is what the miner will see.</h1>
<svg height="100" width="100">
  <circle id="circle" cx="50" cy="50" r="40" stroke="black" stroke-width="3"
  fill="white" />
</svg>
```

HTML

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<h1>This is what the miner will see.</h1>
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```

JavaScript

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  document.getElementById("circle").style.fill="white";
  await msec( 500 );
  return Promise.resolve();
}
async function off(){
  turnOn( Lightbulb );
  document.getElementById("circle").style.fill="gold";
  await msec( 500 );
  turnOff( Lightbulb );
  document.getElementById("circle").style.fill="white";
  await msec( 1500 );
  return Promise.resolve();
}
async function blink(isNumber, value){
  await on();
  //Check if it is number of alphabet.
  if( isNumber ){
    await on();
  }else{
    await off();
  }
  let v = value;
}
```

JavaScript Loop

```
await blink(true, 3); //Code: 3
await msec( 3000 );
await blink(false, 26); //Code: Z
await msec( 3000 );
await blink(false, 1); //Code: A
await msec( 3000 );
await blink(true, 8); //Code: 8
await msec( 10000 );
```

Figure 7 runlinc page

This is what the miner will see.

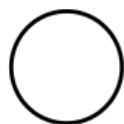


Figure 8 Expected website.

Summary

This further application of the miner problem should introduce you to a simple utilization of the binary numbers in electronics. Instead of counting numbers from the telecommunication section, you can use binary to send more information with less space. Additionally, you would have learned how numerals and letters can be encoded inside the computer. To

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further your understand on how this system works, you should research on ASCII encoding and then Unicode encoding. These will help you in further manipulation of information in computing and in programming.