Reading Binary

Teachers Teaching with Technology™
Professional Development from Texas Instruments

Answers

7 8 **9** **10** 11 12

TI-Nspire Innovator Investigation Student 90 min

Teacher Notes

Two Power Point slide shows have been included to support this activity.

- Reading Binary
- LED Circuit with TI-Innovator

The Reading Binary Power Point provides additional information about data communications, an animation of the data – clock pulse configuration and a brief explanation on how data is synchronised in electronic circuits using devices such as registers.

The LED Circuit with TI-Innovator Power Point provides a step by step construction of the theory and practice of building the LED circuit with the TI-Innovator. The slide show includes the calculations used to determine the size of the resistor, its placement in the circuit and how LED's need to be placed in the circuit including a handy tip to help remember which pin is the 'positive' end of the LED.

The M5 data set that **has not** been referenced in the activity; it can be used to establish a competition between students to see who can read the data most rapidly by decreasing the wait time and being able to convert quickly, binary numbers into decimal and subsequently into text via the ASCII code. The data spells "backwards" however it has been written as "sdrawkcab" so that students are less likely to anticipate the answer prior to the end of the communication. An assessment rubric could include a score dependent on the time taken to read this final message.

Student binary data can be converted to decimal very quickly. This is a two-step process:

- Convert the student's list data into a matrix. Example: list▸Matrix[M1,8] will turn the data in list M1 into a matrix consisting of 8 columns.
- A special matrix has been stored in the document called BD. Multiply the answer to the previous dot-point by matrix BD to obtain the decimal equivalent to the binary data list.

Synchronising Data

A binary signal such as: 1101 is easy to read as numbers but when this is sent as light or electrical signals how does the electrical circuit detect whether two 1's or just a single '1' were received at the start of the signal? The simple answer: "knowing the duration of a single bit". In practical terms this is not as easy as it sounds. A range of protocols are used to streamline digital communications.

In this activity a clock pulse will be sent at the 'same time' as the data[1]. In the case of the TI-Innovator, two LEDs will be used; one LED will be used as a clock pulse advising 'when' to read each bit; the second LED will

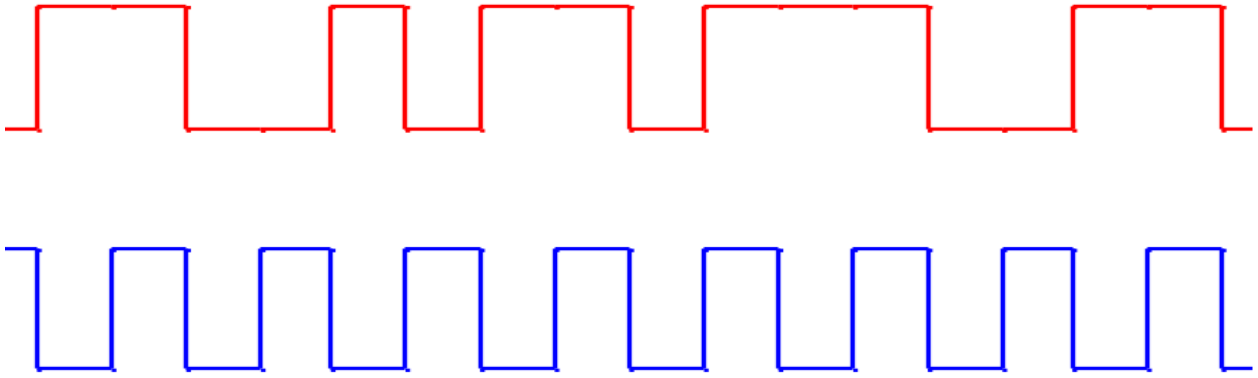
[1] This form of data transmission is more resource heavy than more complex asynchronous communications.

Author: P. Fox

be used to transmit the binary data. As the data will be read by ‘humans’ the transmission will be made slow enough to record the data ‘by-hand’, the speed can be changed as your skill level increases.

The sample data transmission below shows a clock pulse (bottom) and data (top). Look at the data signal, what data do you think is trying to be sent? This diagram illustrates some of the complexities pertaining to data transmission. If the data is read as the clock pulse goes ‘high’ (leading edge), the first data point to be read would be a ‘1’. The second time the clock pulse goes ‘high’ the data is low so a ‘0’ would be read. What state is the data in when the third clock pulse goes ‘high’? This example illustrates the importance of timing.

Now consider data transmission on the trailing edge of the clock pulse? Would the same signal be sent? Would either method result in the intended data transmission? In both these situations square wave forms have been used, real situations involve ramp up / ramp down times which mean the leading and trailing edge are not straight up and down making timing even more critical. With CPU clocks typically running at 1.8GHz the sequence below would take approximately 0.000 000 001 seconds to transmit.

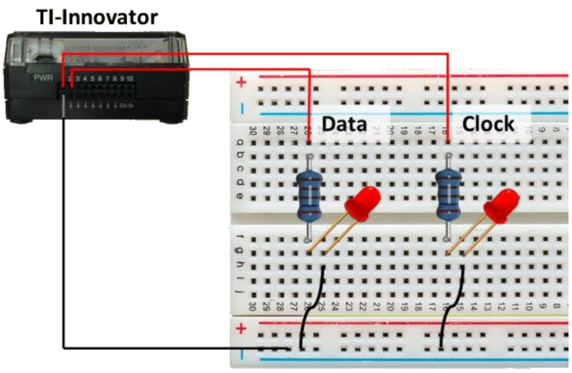


These examples illustrate a very important point when considering the order in which information will be sent from the calculator to the TI-Innovator. Programs read statements sequentially, so it is important that the data be sent to the TI-Innovator before sending the signal to ‘read’.

Constructing the Circuit

In this activity two LED’s will be connected to the TI-Innovator’s power output ports. One LED will be used to display the data; the other will be used as a clock-pulse, a signal to the receiver to read the status of the data LED.

Construct the circuit shown below. Note that the LED connected to power output 1 (PWR 1) will be used as the clock. The LED connected to power output 2 (PWR 2) will be used to transmit data.



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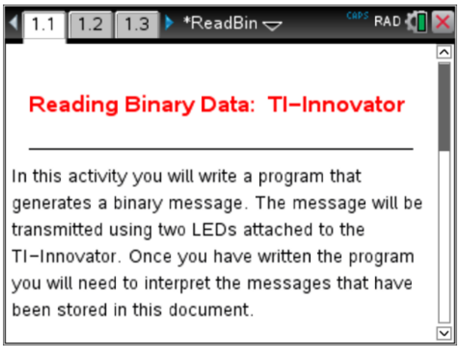
Coding the Algorithm

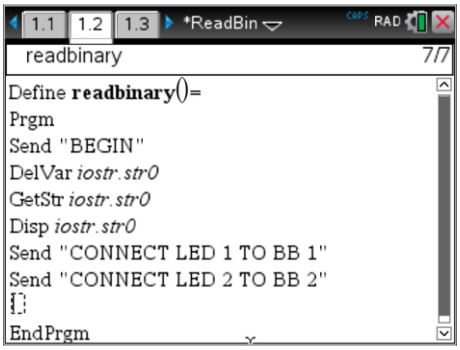
Connect the TI-Innovator hub to your calculator using the Calculator to Calculator cable. The "B" end connects to the Innovator and the "A" end to the calculator.



Open the file called: ReadBinary

The file includes the start of a program that needs to be completed and lots of 'data' that will be used in this activity.

The two LED's need to be set up on TI-Innovator. From the menu select: **Hub** > **Send "Connect – Output** > **LED**



Label the first LED '1' and attach it "**TO**" breadboard location 1:

Hub > **Ports** > **BB 1**

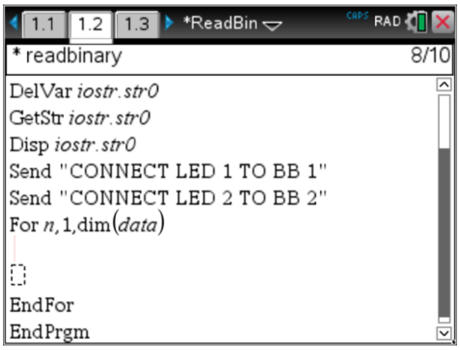
The entire command should: Send "CONNECT LED 1 TO BB 1"

Repeat the above process to set up LED 2 on BB 2.

Notes:

- This program will read binary data stored in a list called "Data". The length of the list will be determined automatically by the program, however the list must only contain 1's and 0's.
- Wait times will be set to 2 seconds. With practice you should be able to read the transmitted information much quicker, too fast however will may lead to errors.

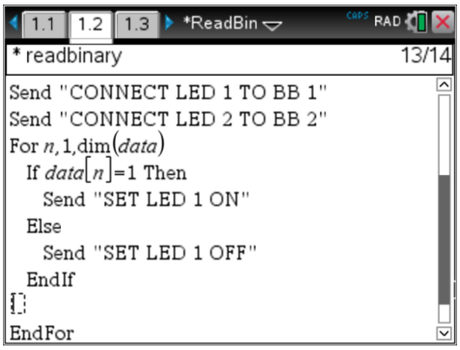
A loop needs to be created to continually and sequentially send the data. The number of times the loop is repeated depends on the amount of data. (Number of bits)



Create a FOR loop that starts at 1 and ends at **DIM**(Data) and uses *n* as the automatic loop counter.

The dimension command can be found in the catalogue or typed directly.

The next step is to check if the data is a '1' or a '0'. If it is a '1' then LED 1 needs to be switched 'ON', otherwise it must be a zero and LED 1 is switched 'OFF'. The screen opposite shows the set of commands to achieve this result.



The "**If … Then … Else … EndIf**" command can be found in the Control menu.

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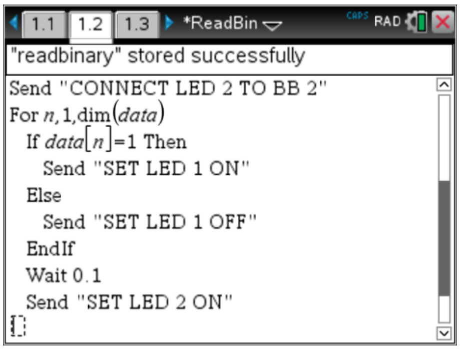
At this point the program is slowed down slightly simulating a small 'ramp up' time. Insert a **WAIT** command immediately after the **EndIf** and have the program wait 0.1 seconds before sending the command to switch the clock pulse on. (LED 2)

Set the clock pulse (LED 2) to come on, shown opposite.

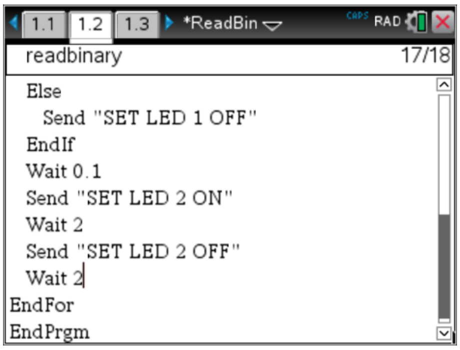


Switching on LED 2 represents the 'leading edge' of the clock pulse. When the program is running, this is the prompt to read the status of LED 1 and record a '1' or a '0'.

Another **WAIT** command is required to allow time to record the status of LED 1, remember, in this activity the 'reading' is being done by humans!

Insert a **WAIT** time of **2** seconds. (This can be changed later.)

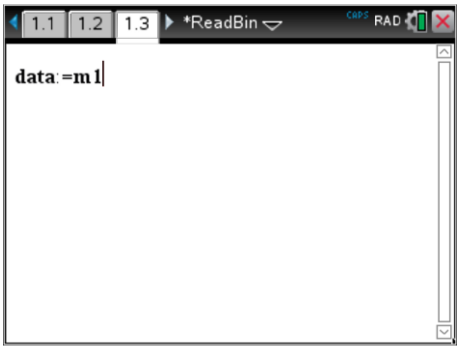
Immediately after the **WAIT** command, switch the clock pulse (LED 2) **OFF**, followed by another WAIT of 2 seconds representing the cyclic ON / OFF of the clock pulse.



Make sure the "EndFor" command is in place and the program is finished.

Navigate to page 1.3. Data has already been stored in this file. To shift the data into the data list type:

data:=m1



Use the VAR key to access the **readbinary** program and run it. Watch how LED 2 switches ON / OFF regularly and LED 1 switches ON / OFF according to the data.

For each of the following questions, work with a friend or two to read, record and translate the messages stored on the calculator.

Question: 1.

Use a stop watch to record how long it takes your team to record, convert and read the binary message. (the entire process below)

- Record binary output from the first message (M1),
- Convert the message binary into decimal
- Convert the decimal into text using ASCII table and hence write out the text message.

Times will vary between students. M1

Binary Data: {0,1,0,0,1,0,0,0,0,1,1,0,0,1,0,1,0,1,1,0,1,1,0,0,0,1,1,0,1,1,0,0,0,1,1,0,1,1,1,1}

Binary Data: {0100 1000, 0110 0101, 0110 110, 0011 0110, 00110 1111}

Decimal Data: 72, 101, 108, 108, 111

Text: Hello [Note the capitalisation of the letter 'H']

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Question: 2.

Edit the program and change the wait times from 2 seconds to 1 second for the on and off signals immediately after each clock pulse for LED 2. (Clock) The message will be sent twice as fast. Once again, use a stop watch to record how long it takes your team to record, convert and read the binary message. Before you start, put second message into the data list: data:=m2 .

Times will vary between students. M2

Binary Data:
{0,1,1,0,1,0,0,1,0,1,1,0,1,1,1,0,0,1,1,0,1,1,1,0,0,1,1,0,1,1,1,1,0,1,1,1,0,1,1,0,0,1,1,0,0,0,0,1,0,1,1,1,0,1,0,0,0,1,1,0,1,0,0,1,0,1,1,0,1,1,1,1,0,1,1,0,1,1,1,0}

Binary Data: {0110 1001, 0110 1110, 0110 1110, 0110 1111, 0111 0110, 0110 0001, 0111 0100, 0110 1001, 0110 1111, 0110 1110}

Decimal Data: 105, 110, 110, 111, 118, 97, 116, 105, 111, 110

Text: innovation

Question: 3.

The messages decoded in Question 1 and 2 are different lengths. Determine the best way to compare the conversion speed for both messages and compare the two conversion times.

Calculate the average amount of time per letter. Conversion times will vary between students.

Question: 4.

Adjust the wait times in the program once again. Store the third message M3 into the data list and start the conversion timing the total conversion time. Record all results as before and the wait time used to convert the message.

Times will vary between students. M3

Binary Data:
{0,1,1,1,0,0,1,1,0,1,1,0,0,0,1,1,0,1,1,0,1,0,0,1,0,1,1,0,0,1,0,1,0,1,1,0,1,1,1,0,0,1,0,1,0,1,0,0,0,1,0,0,1,0,0,1,0,1,1,1,0,0,1,1,0,1,1,1,0,1,0,0}

Binary Data: {0111 0011, 0110 0011, 0110 1001, 0110 0101, 0110 1110, 0101 0100, 0100 1001, 0111 0011, 0111 0100}

Decimal Data: 115,99,105,101,110,84,73,115,116

Text: ScienTIst [Note the capitalisation of TI in the text.]

Question: 5.

There is a mistake in message 4. Determine the message and corresponding mistake.
You may also like to practice your timing.

Times will vary between students. M4

Binary Data:
{0,1,0,1,0,0,1,1,0,1,1,1,0,0,0,0,0,1,1,0,1,1,1,1,0,1,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0,1,1,0,1,0,0,0,0,1,1,0,0,1,0,1,0,0,1,0,0,0,0,0,0,1,1,0,0,1,0,1,0,1,1,1,0,0,1,0,0,1,1,1,0,0,1,0,0,1,1,0,1,1,1,1,0,1,0,1,0,0,1,0}

Binary Data:

{0101 0011, 0111 0000, 0110 1111, 0111 0100, 0010 0000, 0111 0100, 0110 1000, 0110 0101, 0010 0000, 0110 0101, 0111 0010, 0111 0010, 0110 1111, 0101 0010}

Decimal Data: 83,112,111,116,32,116,104,101,32,101,114,114,111,82

Text: Spot the erroR [The 'error' is in the capitalisation of the last R.]

Question: 6.

Would a parity bit check have identified the error?

The difference between ASCII "R" and "r" is one bit. 0101 0010 (R) compared with 0111 0010 (r). So if the data was read incorrectly it is possible that a parity bit check would have located the error. If the '1' parity bit was applied to make the quantity of 1's even then: 0101 0010 would be detected as an error as it contains the incorrect quantity of 1's.

ASCII Table – (Letters only)

A = 65	B = 66	C = 67	D = 68	E = 69	F = 70	G = 71	H = 72	I = 73	J = 74
K = 75	L = 76	M = 77	N = 78	O = 79	P = 80	Q = 81	R = 82	S = 83	T = 84
U = 85	V = 86	W = 87	X = 88	Y = 89	Z = 90				
a = 97	b = 98	c = 99	d =100	e = 101	f = 102	g = 103	h = 104	i = 105	j = 106
k = 107	l = 108	m = 109	n =110	o = 111	p = 112	q = 113	r = 114	s = 115	t = 116
u = 117	v = 118	w = 119	x = 120	y = 121	z = 122				

ASCII Table – (Some Special Characters)

Space = 32	Exclamation = 33	Double Quotes = 34	Dollar Sign = 36	Ampersand = 38
Single Quote = 39	Comma = 44	Hyphen = 45	Period = 46	Forward Slash = 47

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