NYU TANDON SCHOOL OF ENGINEERING

NSF

Promoting robotic design and entrepreneurship experiences among students and teachers

Lesson 12: Advanced Arduino Programming - I

Innovative Technology Experiences for Students and Teachers (ITEST), Professional Development Program, July 2017 - 19

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CONTENTS

- Decimal - binary system
- Math operators

- **TASK/ACTIVITY:** Do it yourself – example problems

DECIMAL TO BINARY CONVERSION

- **Decimal system:** A numeral system whose numbers are represented with **digits 0-9**
- The number is expressed as a **base-10** reference system
  - Examples: 2_{10},5_{10},10_{10}, 100_{10}, etc.

- **Binary system:** A numeral system whose numbers are represented with **digits 0** and **1** only
- The number is expressed as a **base-2** reference system
  - Examples: 00_2, 10_2 (10 is **not 'number ten'** but equals to '**number two'** in the base 2 system), 01_2, 010_2 etc.

DECIMAL TO BINARY CONVERSION

- The process of converting a decimal number to binary number is called **successive division**

- **Process**:

1. Divide the decimal number by 2
2. The remainder is the **Least Significant Bit (LSB)** of binary number
3. The division is continued until the quotient is zero, then the conversion is complete
4. The new remainder is the next **Most Significant Bit (MSB)** of the binary number in every successive division step

DECIMAL TO BINARY CONVERSION

- Example 1: Convert decimal number 6 (base 10) to binary number (base 2)

$$2 \overline{)\,6}\ \begin{matrix}3\\ \\ \end{matrix}$$ Remainder = 0 → LSB

$$2 \overline{)\,3}\ \begin{matrix}1\\ \\ \end{matrix}$$ Remainder = 1 → next MSB

$$2 \overline{)\,1}\ \begin{matrix}0\\ \\ \end{matrix}$$ Remainder = 1 → MSB

$\therefore\ 6_{10} = 110_2$

DEC → BINARY: ACTIVITY

Problem 1: Do it yourself!

Convert the decimal number 26_{10} into its binary equivalent

DEC → BINARY: SOLUTION

Problem 1: Convert the decimal number 26_{10} into its binary equivalent

Solution:

$$2 \overline{)\,26}\ \ 13 \qquad \text{Remainder} = 0 \rightarrow \text{LSB}$$

$$2 \overline{)\,13}\ \ 6 \qquad \text{Remainder} = 1 \rightarrow \text{next MSB}$$

$$2 \overline{)\,6}\ \ 3 \qquad \text{Remainder} = 0$$

$$2 \overline{)\,3}\ \ 1 \qquad \text{Remainder} = 1$$

$$2 \overline{)\,1}\ \ 0 \qquad \text{Remainder} = 1 \rightarrow \text{MSB}$$

$$\therefore\ 26_{10} = 11010_2$$

DEC → BINARY: ACTIVITY

Problem 2: Do it yourself!

Convert the decimal number 41_{10} into its binary equivalent

DEC → BINARY: SOLUTION

Problem 2: Convert the decimal number 41_{10} into its binary equivalent

Solution:

$2 \overline{)\,41}$ — 20 — Remainder = 1 → LSB

$2 \overline{)\,20}$ — 10 — Remainder = 0 → next MSB

$2 \overline{)\,10}$ — 5 — Remainder = 0

$2 \overline{)\,5}$ — 2 — Remainder = 1

$2 \overline{)\,2}$ — 1 — Remainder = 0

$2 \overline{)\,1}$ — 0 — Remainder = 1 → MSB

$\therefore\ 41_{10} = 101001_2$

DEC → BINARY: ACTIVITY

ACTIVITY

a) 13_{10} = ?

b) 22_{10} = ?

c) 43_{10} = ?

d) 158_{10} = ?

DEC → BINARY: SOLUTIONS

a) $13_{10} = ?$ $1\,1\,0\,1_{\,2}$

b) $22_{10} = ?$ $1\,0\,1\,1\,0_{\,2}$

c) $43_{10} = ?$ $1\,0\,1\,0\,1\,1_{\,2}$

d) $158_{10} = ?$ $1\,0\,0\,1\,1\,1\,1\,0_{\,2}$

BINARY TO DECIMAL CONVERSION

- The process of converting a binary number to decimal number is called **weighted multiplication**

- Process:
  1. The decimal number will be equal to the sum of each binary digit starting from the left-most digit times their power of 2 (2^n), n = 0, 1, 2, .., (n – 1) which is called the **bit-weighting factor,** where **n** is the **no. of digits** in the **binary number**
  2. Example: Bit 0 → 2^0 = 1, Bit 1 → 2^1 = 2, Bit 2 → 2^2 = 4, etc.

BINARY TO DECIMAL CONVERSION

Example:

Convert the decimal number 0110_2 into its decimal equivalent where n = 4

Bit 4		Bit 3		Bit 2		Bit 1		
0		1		1		0		
x		x		x		x		
$2^3 = 8$		$2^2 = 4$		$2^1 = 2$		$2^0 = 1$		
ǁ		ǁ		ǁ		ǁ		
0	+	4	+	2	+	0	=	6_{10}

→ n

→ Binary digits

→ Bit-weighting Factors

→ Corresponding decimal digits

$\therefore\ 0110_2 = 6_{10}$

BINARY → DEC: ACTIVITY

Problem 1: Do it yourself!

Convert the binary number 10010_2 into its decimal equivalent where n = 6

BINARY → DEC: SOLUTION

Problem 1: Convert the binary number 10010 into its decimal equivalent where n = 5

Solution:

Bit 5		Bit 4		Bit 3		Bit 2		Bit 1		
1		0		0		1		0		
X		X		X		X		X		
$2^4 = 16$		$2^3 = 8$		$2^2 = 4$		$2^1 = 2$		$2^0 = 1$		
‖		‖		‖		‖		‖		
16	+	0	+	0	+	2	+	0	=	18_{10}

$\therefore 10010_2 = 18_{10}$

BINARY → DEC: ACTIVITY

a) 0110_2 = ?

b) 11010_2 = ?

c) 0110101_2 = ?

d) 11010011_2 = ?

BINARY → DECIMAL : SOLUTIONS

a) 0110_2 = ? 6_{10}

b) 11010_2 = ? 26_{10}

c) 0110101_2 = ? 53_{10}

d) 11010011_2 = ? 211_{10}

DECIMAL AND BINARY – REVIEW

Base$_{10}$ DECIMAL → **Successive Division** → **Base$_2$ BINARY**

a) Divide the decimal number by 2, remainder = **LSB** of binary number

b) If the quotient = zero, the conversion is complete; else repeat step (a) using the quotient = decimal number and new remainder = next **MSB** of the binary number

Base$_2$ BINARY → **Weighted Multiplication** → **Base$_{10}$ DECIMAL**

a) Multiply each bit of the binary number by it corresponding **bit-weighting factor** (i.e., Bit - 0 $\rightarrow 2^0 = 1$, Bit – 1 $\rightarrow 2^1 = 2$, etc.)

b) **Sum** up all the products in step (a) to get the decimal number

MATH OPERATORS

- **abs(x):** absolute value of x (applicable if x = int and long)
- **fabs(x):** absolute value of x (applicable if x = float)
- **min(x, y)** and **max(x, y):** minimum and maximum of two arguments x and y
- **pow(x, y):** x ^ y
- **sq(x):** x ^ 2
- **Trigonometric functions: sin(x), cos(x),** x has to be in radians
- **random(max):** generates a random number between 0 and max
- **random(min, max):** generates a random number between min and max

MATH OPERATOR

ACTIVITY

1. Write a program to display minimum of the absolute values of 40 and -30

1. Write a program to find the value of $\sin(x) + (\cos(x))^2$ at x = 1.5 radians

MATH OPERATOR – SOLUTION FOR 1st

Minimum_value | Arduino 1.8.19

File Edit Sketch Tools Help

Minimum_value §

```
int x = 30;
int y = -40;
void setup() {
  Serial.begin(9600);

  int z = min(x, y);

  Serial.print("x    = ");
  Serial.println(x);
  Serial.print("y    = ");
  Serial.println(y);
  Serial.print("Minimum value of 40 and -30 = ");
  Serial.println(z);
}

void loop() {}
```

OUTPUT:
The minimum value of the array is: -40

MATH OPERATOR – SOLUTION FOR 2nd

Equation_with_angles | Arduino 1.8.19

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Equation_with_angles §

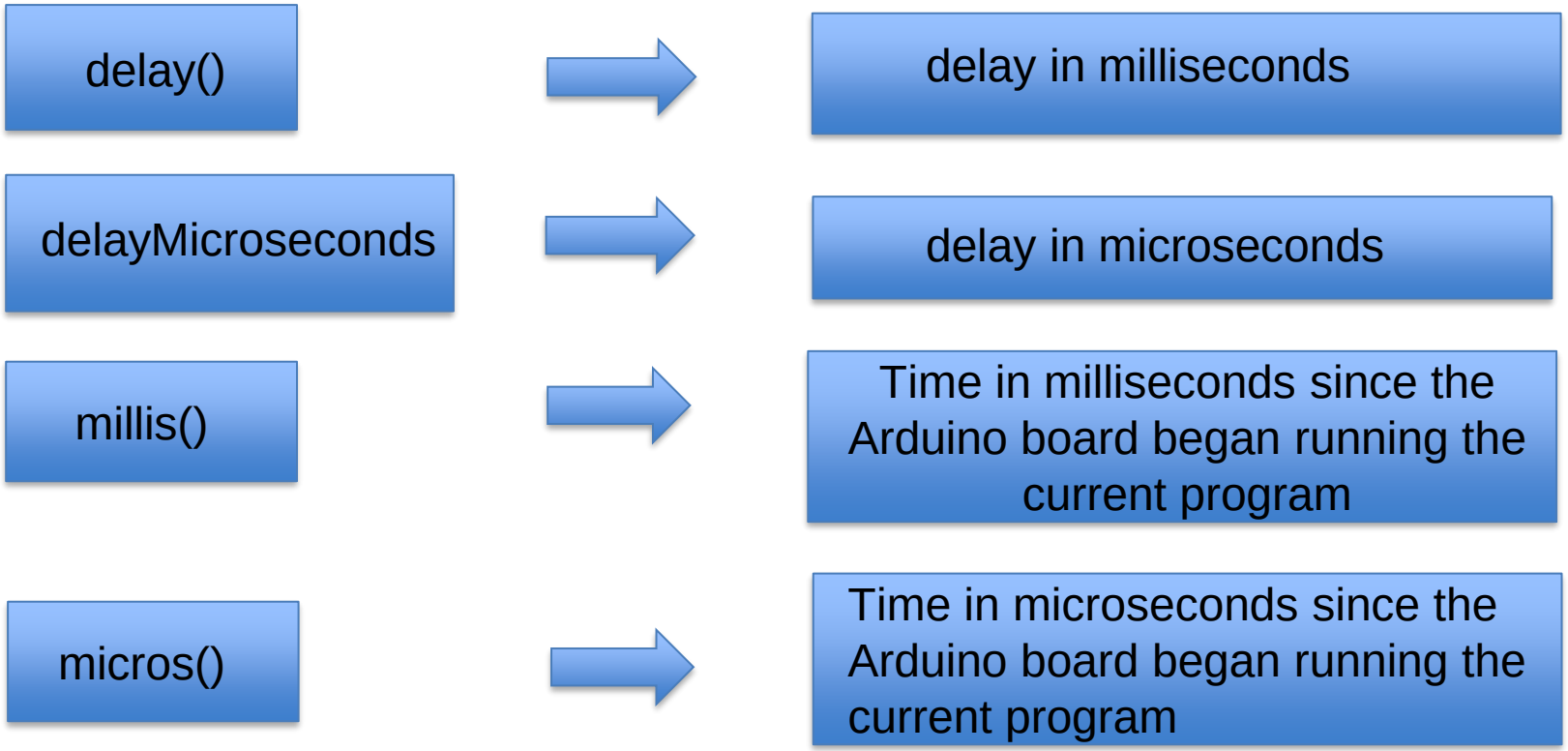
```
int angle=1.5; // in radians
int val;

void setup() {
// put your setup code here, to run once:
Serial.begin(9600);
val = sin(angle) + sq(cos(angle));
Serial.print("The value of the equation at 1.5 radians is: ");
Serial.println(val);
}

void loop() {}
```

OUTPUT:
The value of the equation at 1.5 radians is: 1

PROGRAMMING: OTHERS



MILLIS FUNCTION EXAPMLE

Millis_functionExample | Arduino 1.8.19

File Edit Sketch Tools Help

Millis_functionExample §

```
const int ledPin =  3; // the LED pin number connected
int ledState = LOW;             // set the LED state initially LOW
unsigned long previousMillis = 0;  //will store last time LED was blinked
const long period = 1000;          // period at which to blink in ms

void setup() {
  pinMode(ledPin, OUTPUT); // set ledpin as output
}

void loop() {
 unsigned long currentMillis = millis(); // store the current time
  if (currentMillis - previousMillis >= period) { // check if 1000ms passed
   previousMillis = currentMillis;   // save the last time you blinked the LED
   if (ledState == LOW) { // if the LED is off turn it on and vice-versa
     ledState = HIGH;
   } else {
ledState = LOW;}
   digitalWrite(ledPin, ledState);//set LED with ledState to blink again
   }
}
```

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Thank You!

Questions and Feedback?