Digital Design through Pi

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CONTENTS

***Abstract*—This manual covers the entire breadth of digital design by building a decade counter using a Raspberry Pi. In the process, boolean logic, combinational logic and sequential logic are covered.**

1 Display Control through Hardware

1.1 Components

The components required for this manual are listed in Table 1.1

1.2 Software Setup

The following commands will install the Wiring Pi module [2]

```
sudo apt-get install git-core
sudo apt-get update
sudo apt-get upgrade
cd
```

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Component	Value	Quantity
Breadboard		1
Resistor	$\geq 220\Omega$	1
Pi	Model B, Rev 3	1
Seven Segment Display	Common Anode	1
Decoder	7447	1
Flip Flop	7474	2
Jumper Wires	Female-Male	20

TABLE 1.1

```
git clone git://git.drogon.net/
    wiringPi
cd ~/wiringPi
./build
```

1.3 Powering the Display

The breadboard can be divided into 5 segments. In each of the green segements, the pins are internally connected so as to have the same voltage. Similarly, in the central segments, the pins in each column are internally connected in the same fashion as the blue columns.

Problem 1.1. Plug the display to the breadboard in Fig. 1.1

The seven segment display in Fig. 1.2 has eight pins, a, b, c, d, e, f, g and *dot* that take an active LOW input, i.e. the LED will glow only if the input is connected to ground. Each of these pins is connected to an LED segment. The *dot* pin is reserved for the $\cdot$ LED.

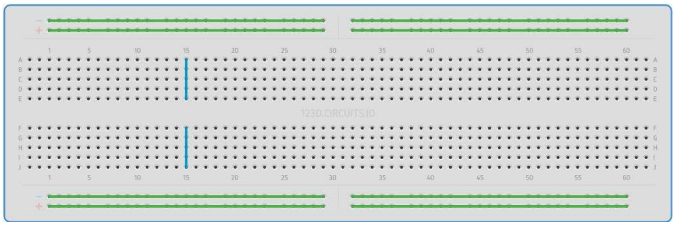

Fig. 1.1

Problem 1.2. Connect one end of the resistor to the COM pin of the display and the other end to an extreme pin of the breadboard.

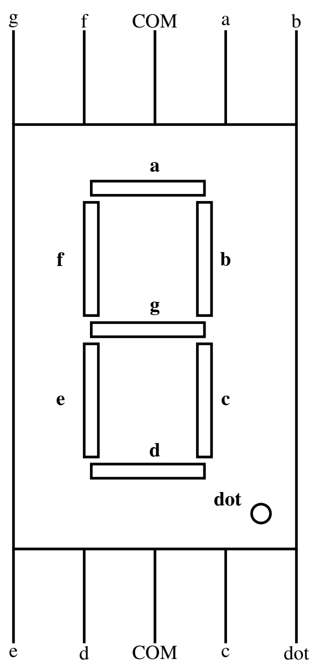

Fig. 1.2

The Raspberry Pi 3 has 40 pins (see Figs. 2.1.1 and 2.1.2), which include power pins that can generate 5V and 3.3V, GND pins, PWM pins, pins for wired communication and some free pins for digital I/O. In the following exercises, only the GND, $5V$ and digital I/O pins will be used.

Problem 1.3. Connect pin 2 (5V) of the Pi to an extreme pin that is in the same segment as the resistor pin.

Problem 1.4. Connect pin 6 (GND) of the Pi to the opposite extreme pin of the breadboard

Problem 1.5. Connect the *dot pin of the display to a pin in the same segment as the GND pin. What do you observe?*

1.4 Controlling the Display

Fig. 1.6 explains how to get decimal digits using the seven segment display.

Problem 1.6. Generate the number 1 on the display by connecting only the pins b and c to GND.

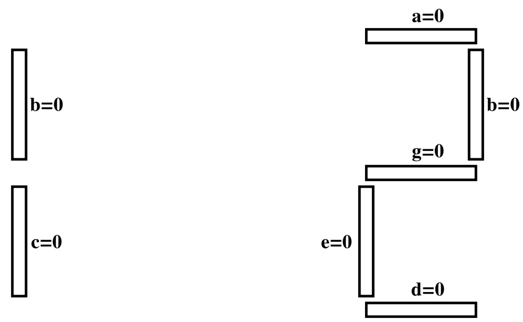

Fig. 1.6

Problem 1.7. Repeat the above exercise to generate the number 2 on the display.

Problem 1.8. Table 1.8 summarizes the process of generating the decimal digits. 0 means connecting to ground and 1 means not connecting. Complete Table 1.8 for all numbers between 0-9.

a	b	c	d	e	f	g	decimal
1	0	0	1	1	1	1	1
0	0	1	0	0	1	0	2

TABLE 1.8

Problem 1.9. Now generate all numbers between 0-9 on the display using the above table.

The 7447 IC helps in displaying decimal numbers on the seven segment display. The $\bar{a} - \bar{g}$, pins of the 7447 IC are connected to the $a - g$ pins of the display. V_{cc} should be connected to a 5V power source. The input pins of the decoder are A,B,C and D, with A being the lowest significant bit (LSB) and D being the most significant bit (MSB). For example, the number 5 is visible on the display when the A,B,C and D inputs are the following.

D	C	B	A	Decimal
0	1	0	1	5

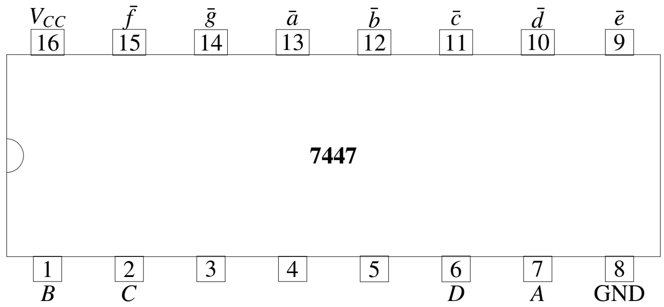

Fig. 1.9

Problem 1.10. Connect the 7447 IC decoder $\bar{a}-\bar{g}$ pins to the $a-g$ pins of the display respectively.

Problem 1.11. Connect the V_{cc} and GND pins of the decoder to the 5V supply and GND pins of the breadboard.

Problem 1.12. Connect the A,B,C,D pins to pins in the GND extreme segment of the breadboard. What do you observe.

Problem 1.13. Now remove the D pin from the breadboard and observe the display output.

Problem 1.14. Generate a table with A,B,C,D inputs and the equivalent decimal number output.

2 Display Control through Software

2.1 Driving the Segments

Problem 2.1. Connect the A-D pins of the 7447 IC in Fig. 1.9 to the GPIO pins 0-3 of the Pi shown in Figs. 2.1.1 and 2.1.2.

Fig. 2.1.1: GPIO pin snapshot on Pi [1].

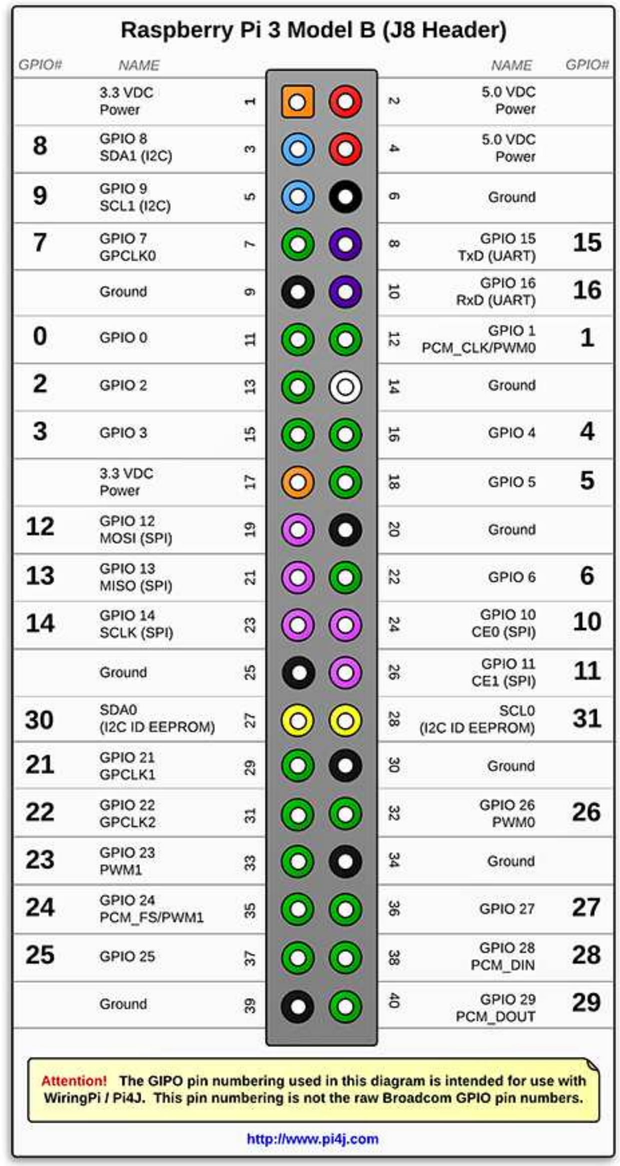

Fig. 2.1.2: GPIO Wiring Pi [2] pin configuration.

Problem 2.2. Type the following code and execute. What do you observe?

```
#include <wiringPi.h>
int main (void)
{
  wiringPiSetup () ;
  pinMode (0, OUTPUT) ;
  pinMode (1, OUTPUT) ;
  pinMode (2, OUTPUT) ;
  pinMode (3, OUTPUT) ;
  for (;;)
  {
   digitalWrite (0, 1);
   digitalWrite (1, 0) ;
   digitalWrite (2, 1) ;
   digitalWrite (3, 0) ;
  }
  return 0 ;
}
```

Z	Y	X	W	**D**	**C**	**B**	**A**
0	0	0	0	**0**	**0**	**0**	**1**
0	0	0	1	**0**	**0**	**1**	**0**
0	0	1	0	**0**	**0**	**1**	**1**
0	0	1	1	**0**	**1**	**0**	**0**
0	1	0	0	**0**	**1**	**0**	**1**
0	1	0	1	**0**	**1**	**1**	**0**
0	1	1	0	**0**	**1**	**1**	**1**
0	1	1	1	**1**	**0**	**0**	**0**
1	0	0	0	**1**	**0**	**0**	**1**
1	0	0	1	**0**	**0**	**0**	**0**

TABLE 2.4

```
//Command for raspberry pi
//Save file as bcd_seven.c
//gcc -Wall -o test bcd_seven.c -
    lwiringPi
//followed by
// sudo ./test
```

Problem 2.3. Now generate the numbers 0-9 by modifying the above program.

2.2 Counting Decoder

In the truth table in Table 2.4, W, X, Y, Z are the inputs and A, B, C, D are the outputs. This table represents the system that increments the numbers 0-8 by 1 and resets the number 9 to 0 Note that $D = 1$ for the inputs 0111 and 1000. Using *boolean* logic,

$$D = WXYZ' + W'X'Y'Z \tag{2.3.1}$$

Note that 0111 results in the expression $WXYZ'$ and 1000 yields $W'X'Y'Z$.

Problem 2.4. Write the boolean logic functions for A, B, C in terms of W, X, Y, Z.

Problem 2.5. Write a program for implementing Table 2.4.

Solution:

```
#include <wiringPi.h>
int main (void)
{
  int Z=0,Y=0,X=1,W=1;
  int D,C,B,A;
  wiringPiSetup () ;
  pinMode (0, OUTPUT) ;
  pinMode (1, OUTPUT) ;
  pinMode (2, OUTPUT) ;
  pinMode (3, OUTPUT) ;
  for (;;)
  {

  D = (W&&X&&Y&&!Z) || (!W&&!X&&!Y
     &&Z);
  C = (W&&X&&!Y&&!Z) || (!W&&!X&&Y
     &&!Z) || (W&&!X&&Y&&!Z) || (!W
     &&X&&Y&&!Z);
  B = (W&&!X&&!Y&&!Z) || (!W&&X&&!
     Y&&!Z) || (W&&!X&&Y&&!Z) || (!
     W&&X&&Y&&!Z);
  A = (!W&&!X&&!Y&&!Z) || (!W&&X
     &&!Y&&!Z) || (!W&&!X&&Y&&!Z)
     || (!W&&X&&Y&&!Z) || (!W&&!X
     &&!Y&&Z);


    digitalWrite (0, A);
    digitalWrite (1, B) ;
    digitalWrite (2, C) ;
    digitalWrite (3, D) ;
  }
  return 0 ;
}
```

Problem 2.6. Verify if your logic is correct by observing the output on the seven segment display for different inputs.

Problem 2.7. Connect GPIO pin 10 to the dot pin of the display and execute the following code.

```
#include <wiringPi.h>
int main (void)
{
  wiringPiSetup () ;
  pinMode (10, OUTPUT) ;
  for (;;)
  {
    digitalWrite (10, HIGH) ;
      delay (500) ;
    digitalWrite (10, LOW) ;
      delay (500) ;

  }
```

```
    return 0 ;
}
```

Problem 2.8. A decade counter counts the numbers from 0-9 and then resets to 0. Suitable modify the above programs to obtain a decade counter.

2.3 Display Decoder

Problem 2.9. Now write the truth table for the seven segment display decoder (IC 7447). The inputs will be A, B, C, D and the outputs will be a, b, c, d, e, f, g.

Problem 2.10. Obtain the logic functions for outputs a, b, c, d, e, f, g in terms of the inputs A, B, C, D.

Problem 2.11. Disconnect the Pi from IC 7447 and connect the pins GPIO 0-6 in the Pi directly to the seven segment display.

Problem 2.12. Write a new program to implement the logic in Problem 2.10 and observe the output in the display. You have designed the logic for IC 7447!

Problem 2.13. Now include your counting decoder program in the display decoder program and see if the display shows the consecutive number.

3 Decade Counter through Flip-Flops

The 7474 IC in Fig. 3.0 has two D flip flops. The D pins denote the input and the Q pins denote the output. CLK denotes the clock input.

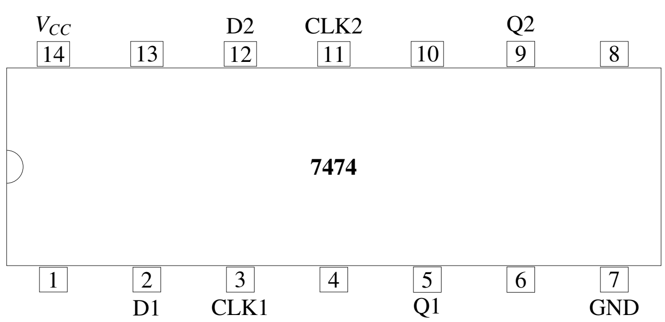

Fig. 3.0

Problem 3.1. Connect the 0-3 pins of the Pi to the Q pins of the two 7474 ICs. Use the 0-3 pins as Pi input.

Problem 3.2. Connect the Q pins to IC 7447 Decoder as input pins. Connect the 7447 IC to the seven segment display.

Problem 3.3. Connect the 11-14 pins of the Pi to the D input pins of two 7474 ICs. Use the 11-14 pins as Pi output.

Problem 3.4. Connect pin 10 of the Pi to the CLK inputs of both the 7474 ICs.

Problem 3.5. Connect pins 1,4,10 and 13 of both the 7474 ICs to 5V.

Problem 3.6. Using the logic for the counting decoder in the Pi software, implement the decade counter.

References

[1] [Online]. Available: http://pi4j.com/pins/model-2b-rev1.html
[2] [Online]. Available: http://wiringpi.com/