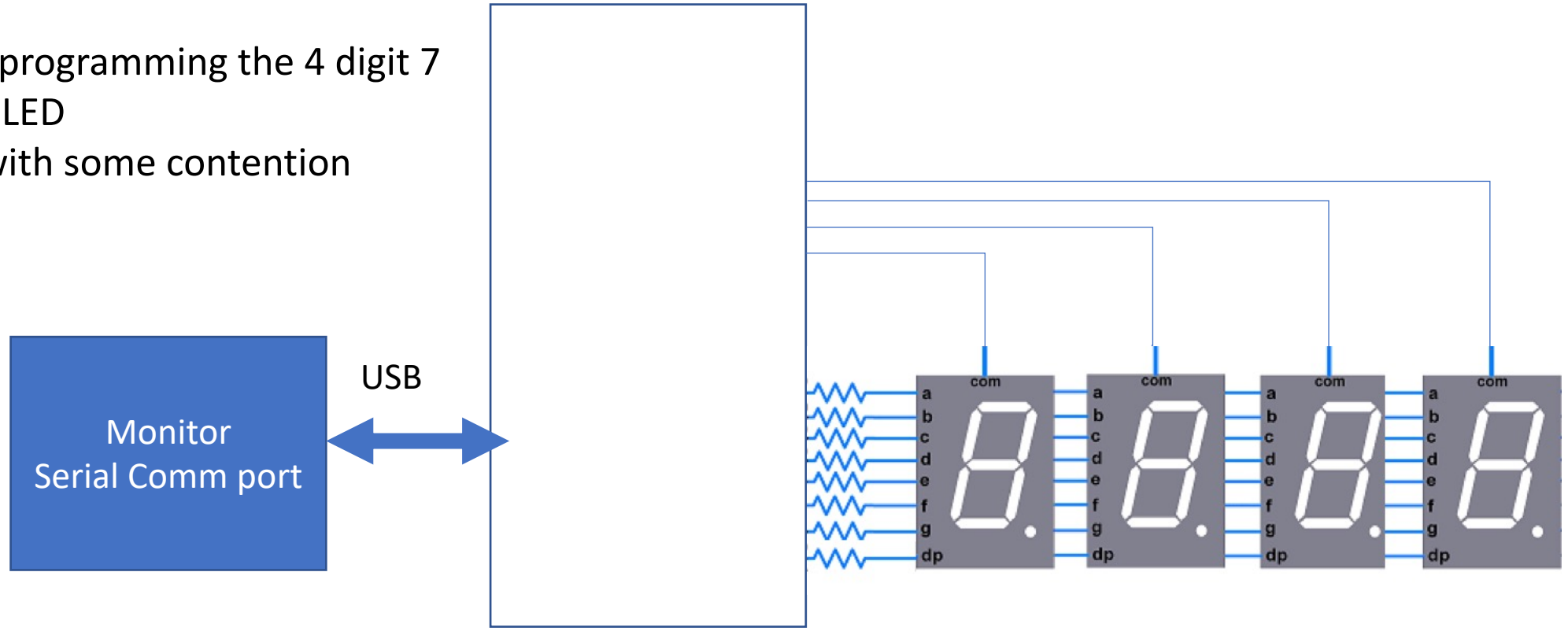
# 8.6 Retinal Persistence and the 4 digit, 7-segment LED.

ECE-231
Prof. McLaughlin
Spring 2024

Let’s build a four digit ring counter (0000 – 9999) that displays digits on a serial monitor and on  the 4-digit 7-segment display.

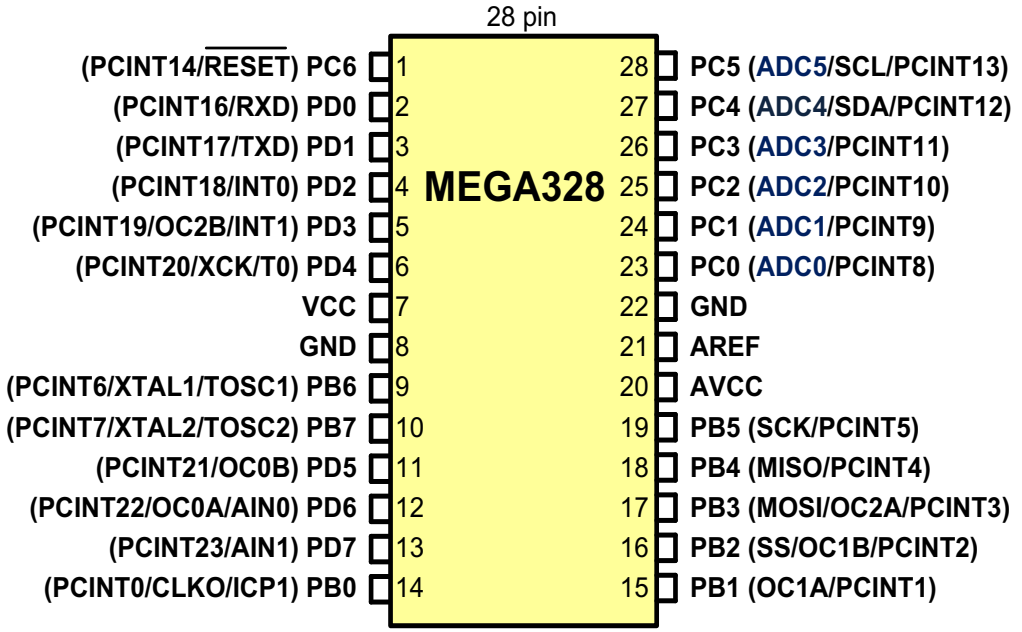
Topics:

- sending digits to serial monitor via UART
- wiring & programming the 4 digit 7 segment LED
- dealing with some contention issues



Sending digits to serial monitor via UART:

write a program that implements a 4 digit ring counter (0-9999, then repeat), sending the count via UART to the serial monitor.



serialwow.c > ...

```c
/*****************************************************************
 * serialcomm_main.c - this program continuously sends
 * the letter 'WOW!' to the serial monitor via the UART on the ATmega328P MCU.
 * Date         Author          Revision
 * 3/1/22       D. McLaughlin   initial release. based on serialcomm_main.c
 *****************************************************************/

#include <avr/io.h>             // Defines constants USCR0B, USCR0C, etc...

void uart_init(void);           // Function prototype (declaration)
void send_char(char);           // Function prototype (declaration)

int main(void){                 // Main function definition

    uart_init();                // Initialize the UART

    while (1) {                 // Send repeatedly
        send_char('W');
        send_char('o');
        send_char('W');
        send_char(10);          // Carriage Return
        send_char(13);          // Line feed
    }
}

// This function initializes the UART peripheral
// enable; 8 data bits; 1 stop bit, no parity
// 9600 baud from 16 MHz clock
void uart_init(void)  {
    UCSR0B = (1<<TXEN0);
    UCSR0C = (1<< UCSZ01)|(1<<UCSZ00);
    UBRR0L = 103; // Gives us 9600 baud from 16 MHz clock
}

// This function sends a single character to the serial comm port
void send_char(char letter){
    while (! (UCSR0A&(1<<UDRE0))); // Wait until Tx buffer is empty
    UDR0=letter;
}
/******** End of File *************/
```

C uart_string.c > ...

```c
/*****************************************************************
 * uart_string.c - This code sends strings to com port via uart.
 * Date     Author          Revision
 * 12/16/21 D. McLaughlin   Initial writing of the code
 * 1/15/22  D. McLaughlin   Tested on Arduino Uno w/ Apple M1 pro
 *                          host running Monterey
 * 2/27/22  D. McLaughlin   tested on Windows 11 on Parallels VM
 *****************************************************************/
#include <avr/io.h>
#include <util/delay.h>
#include <string.h>  //so that we can use the  strlen() function

void uart_init(void);
void uart_send(unsigned char);
void send_string(char *stringAddress);

int main(void){
    char mystring[]= "Shall I compare thee to a summer's day?";
    uart_init(); // initialize the USART
    while (1) {
        send_string(mystring);
        uart_send(13); // Carriage return (goto beginning of line)
        uart_send(10); //line feed (new line)
        _delay_ms(500);
    }
}

// Send a string, char by char, to uart via uart_send()
// Input is pointer to the string to be sent
void send_string(char *stringAddress){
    for (unsigned char i = 0; i < strlen(stringAddress); i++)
        uart_send(stringAddress[i]);
}

> void uart_init(void){…

> void uart_send(unsigned char ch){…

/***** End of file *****/
```

we are making use of 3 user-defined functions:
uart_init()  uart_send()  send_string()

ASCII Codes:

| Dec | Hex | Ch |
|---|---|---|
| 32 | 20 | |
| 33 | 21 | ! |
| 34 | 22 | " |
| 35 | 23 | # |
| 36 | 24 | $ |
| 37 | 25 | % |
| 38 | 26 | & |
| 39 | 27 | ' |
| 40 | 28 | ( |
| 41 | 29 | ) |
| 42 | 2A | * |
| 43 | 2B | + |
| 44 | 2C | , |
| 45 | 2D | - |
| 46 | 2E | . |
| 47 | 2F | / |
| 48 | 30 | 0 |
| 49 | 31 | 1 |
| 50 | 32 | 2 |
| 51 | 33 | 3 |
| 52 | 34 | 4 |
| 53 | 35 | 5 |
| 54 | 36 | 6 |
| 55 | 37 | 7 |
| 56 | 38 | 8 |
| 57 | 39 | 9 |
| 58 | 3A | : |
| 59 | 3B | ; |
| 60 | 3C | < |
| 61 | 3D | = |
| 62 | 3E | > |
| 63 | 3F | ? |

| Dec | Hex | Ch |
|---|---|---|
| 64 | 40 | @ |
| 65 | 41 | A |
| 66 | 42 | B |
| 67 | 43 | C |
| 68 | 44 | D |
| 69 | 45 | E |
| 70 | 46 | F |
| 71 | 47 | G |
| 72 | 48 | H |
| 73 | 49 | I |
| 74 | 4A | J |
| 75 | 4B | K |
| 76 | 4C | L |
| 77 | 4D | M |
| 78 | 4E | N |
| 79 | 4F | O |
| 80 | 50 | P |
| 81 | 51 | Q |
| 82 | 52 | R |
| 83 | 53 | S |
| 84 | 54 | T |
| 85 | 55 | U |
| 86 | 56 | V |
| 87 | 57 | W |
| 88 | 58 | X |
| 89 | 59 | Y |
| 90 | 5A | Z |
| 91 | 5B | [ |
| 92 | 5C | \ |
| 93 | 5D | ] |
| 94 | 5E | ^ |
| 95 | 5F | _ |

| Dec | Hex | Ch |
|---|---|---|
| 96 | 60 | ` |
| 97 | 61 | a |
| 98 | 62 | b |
| 99 | 63 | c |
| 100 | 64 | d |
| 101 | 65 | e |
| 102 | 66 | f |
| 103 | 67 | g |
| 104 | 68 | h |
| 105 | 69 | i |
| 106 | 6A | j |
| 107 | 6B | k |
| 108 | 6C | l |
| 109 | 6D | m |
| 110 | 6E | n |
| 111 | 6F | o |
| 112 | 70 | p |
| 113 | 71 | q |
| 114 | 72 | r |
| 115 | 73 | s |
| 116 | 74 | t |
| 117 | 75 | u |
| 118 | 76 | v |
| 119 | 77 | w |
| 120 | 78 | x |
| 121 | 79 | y |
| 122 | 7A | z |
| 123 | 7B | { |
| 124 | 7C | \| |
| 125 | 7D | } |
| 126 | 7E | ~ |
| 127 | 7F | ⌂ |

Send (transmit) the string: “Wow!”

```
uart_send(‘W’);
uart_send(‘o’);
uart_send(’w’);
uart_send(‘!’);
```

or

```
uart_send(87);
uart_send(111);
uart_send(119);
uart_send(33);
```

or

```
send_string(“Wow!”)
```

we are making use of 3 user-defined functions:
uart_init()  uart_send()  send_string()

ASCII Codes:

| Dec | Hex | Ch |
|---|---|---|
| 32 | 20 | |
| 33 | 21 | ! |
| 34 | 22 | " |
| 35 | 23 | # |
| 36 | 24 | $ |
| 37 | 25 | % |
| 38 | 26 | & |
| 39 | 27 | ' |
| 40 | 28 | ( |
| 41 | 29 | ) |
| 42 | 2A | * |
| 43 | 2B | + |
| 44 | 2C | , |
| 45 | 2D | - |
| 46 | 2E | . |
| 47 | 2F | / |
| 48 | 30 | 0 |
| 49 | 31 | 1 |
| 50 | 32 | 2 |
| 51 | 33 | 3 |
| 52 | 34 | 4 |
| 53 | 35 | 5 |
| 54 | 36 | 6 |
| 55 | 37 | 7 |
| 56 | 38 | 8 |
| 57 | 39 | 9 |
| 58 | 3A | : |
| 59 | 3B | ; |
| 60 | 3C | < |
| 61 | 3D | = |
| 62 | 3E | > |
| 63 | 3F | ? |

| Dec | Hex | Ch |
|---|---|---|
| 64 | 40 | @ |
| 65 | 41 | A |
| 66 | 42 | B |
| 67 | 43 | C |
| 68 | 44 | D |
| 69 | 45 | E |
| 70 | 46 | F |
| 71 | 47 | G |
| 72 | 48 | H |
| 73 | 49 | I |
| 74 | 4A | J |
| 75 | 4B | K |
| 76 | 4C | L |
| 77 | 4D | M |
| 78 | 4E | N |
| 79 | 4F | O |
| 80 | 50 | P |
| 81 | 51 | Q |
| 82 | 52 | R |
| 83 | 53 | S |
| 84 | 54 | T |
| 85 | 55 | U |
| 86 | 56 | V |
| 87 | 57 | W |
| 88 | 58 | X |
| 89 | 59 | Y |
| 90 | 5A | Z |
| 91 | 5B | [ |
| 92 | 5C | \ |
| 93 | 5D | ] |
| 94 | 5E | ^ |
| 95 | 5F | _ |

| Dec | Hex | Ch |
|---|---|---|
| 96 | 60 | ` |
| 97 | 61 | a |
| 98 | 62 | b |
| 99 | 63 | c |
| 100 | 64 | d |
| 101 | 65 | e |
| 102 | 66 | f |
| 103 | 67 | g |
| 104 | 68 | h |
| 105 | 69 | i |
| 106 | 6A | j |
| 107 | 6B | k |
| 108 | 6C | l |
| 109 | 6D | m |
| 110 | 6E | n |
| 111 | 6F | o |
| 112 | 70 | p |
| 113 | 71 | q |
| 114 | 72 | r |
| 115 | 73 | s |
| 116 | 74 | t |
| 117 | 75 | u |
| 118 | 76 | v |
| 119 | 77 | w |
| 120 | 78 | x |
| 121 | 79 | y |
| 122 | 7A | z |
| 123 | 7B | { |
| 124 | 7C | \| |
| 125 | 7D | } |
| 126 | 7E | ~ |
| 127 | 7F | ⌂ |

6 ways to transmit the letter G

```
uart_send('G');
uart_send(71);
uart_send(0x47);
uart_send(6+65);
uart_send(6+'A');
send_string("G");        // strings in " "
```

6 ways to transmit the number 4

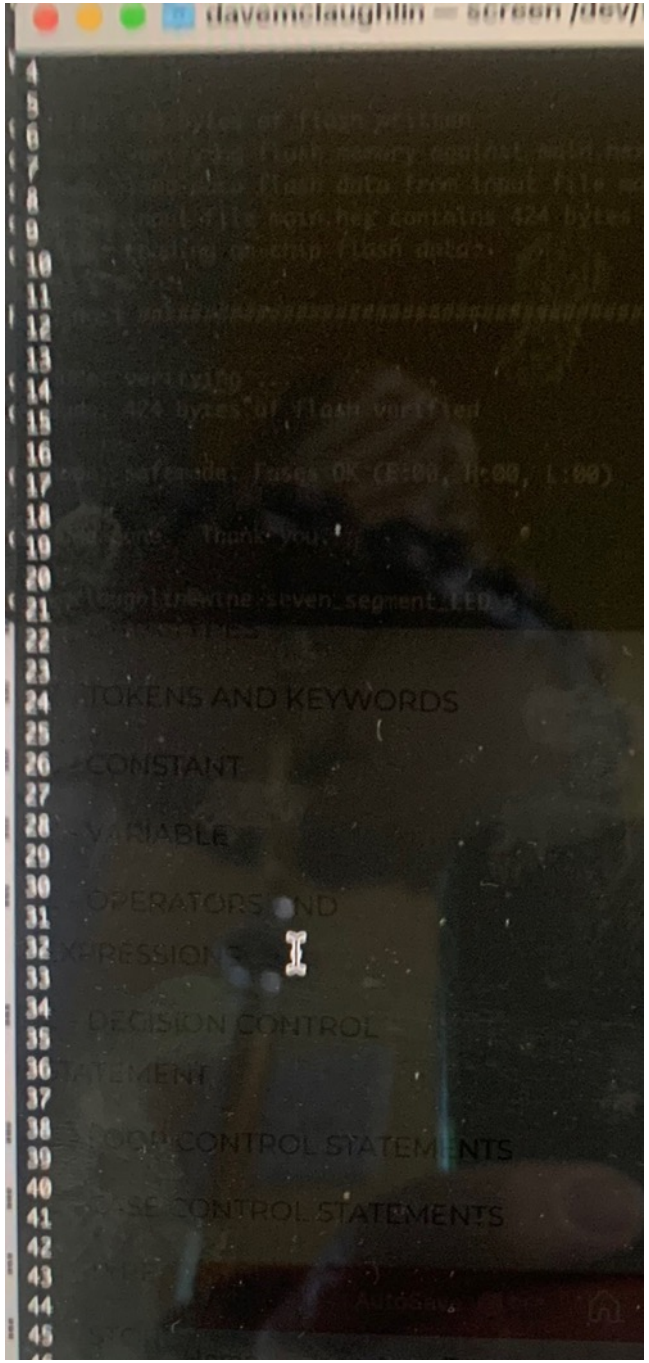
```
uart_send('4');
uart_send(52);
uart_send(0x34);
uart_send(4+48);
uart_send(4+'0');
send_string("4");
```

counter_uart.c — seven_segment_LED

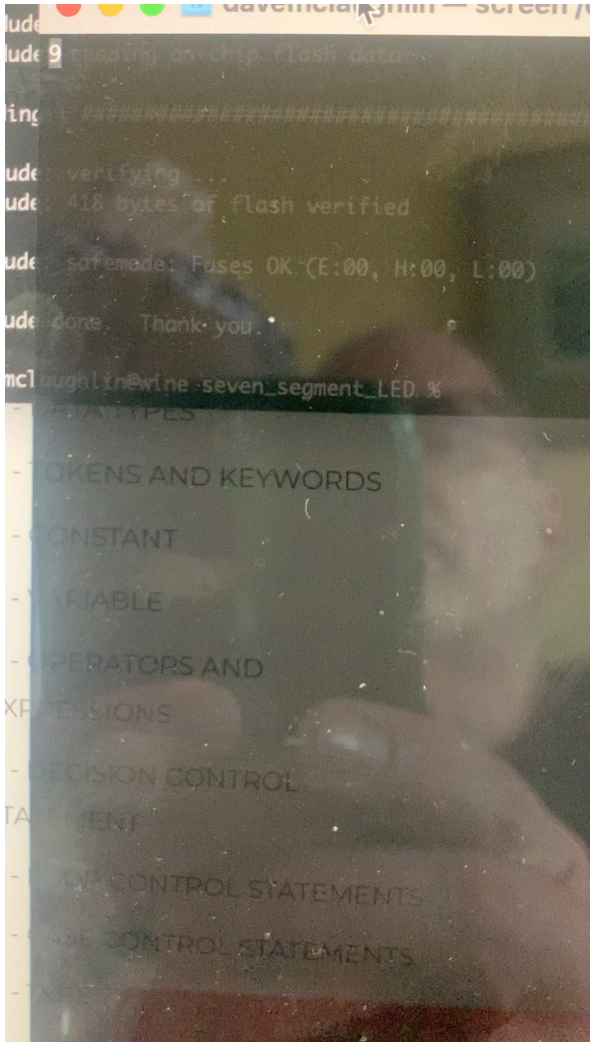
_main.c | counter_uart.c | counter_uart2.c | makefile

counter_uart.c > main(void)

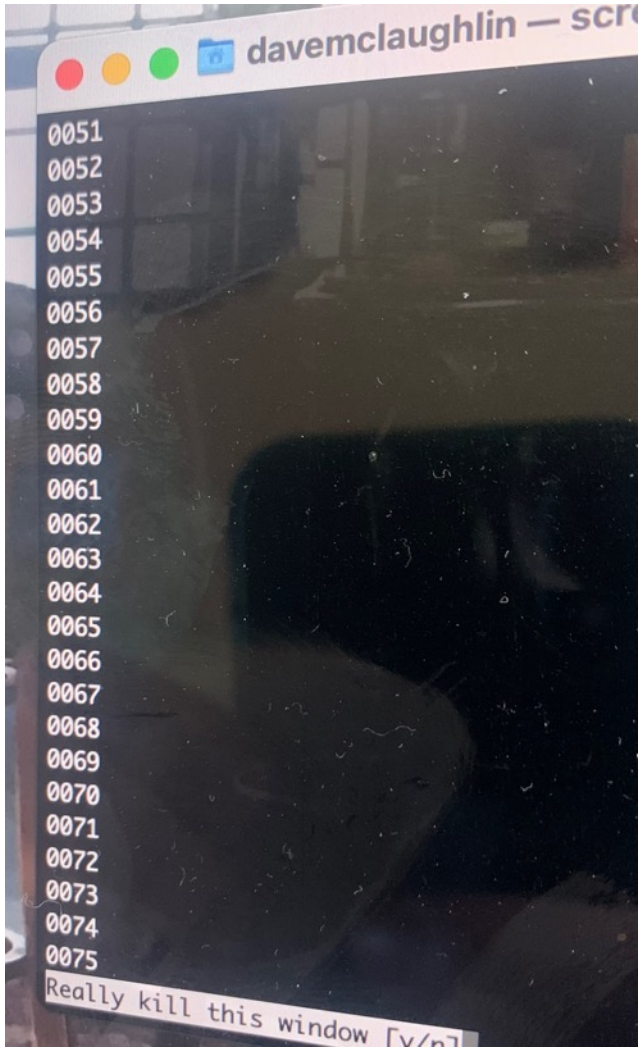
```c
/* counter_uart.c This code implements a 0- 9999 ring counter
and displays the count value on the monitor using the UART.
Uses itoa() function to convert count to a string.
This is a demo for ECE-231 Spring 2022
D. McLaughlin 3/18/22 */

#include <avr/io.h>     // #defines all the port pins
#include <util/delay.h> // Declares _delay_ms() function
#include <stdlib.h>     // Declares itoa() function
#include <string.h>     // Declares strlen() function

void uart_init(void);
void uart_send(unsigned char);
void send_string(char *stringAddress);

int main(void){
    char mystring[10];
    uart_init(); // initialize the USART
    while (1) {
        for (unsigned int i=0; i<10000; i++){
            itoa(i, mystring, 10); // Convert i to a string, base 10
            send_string(mystring);
            uart_send(13); // Carriage return (goto beginning of line)
            uart_send(10); //line feed (new line)
            _delay_ms(1000);
        }

    }
}

// Send a string, char by char, to uart via uart_send()…
void send_string(char *stringAddress){…

// Initialize the uart, 8,1,0, 9600 baud
void uart_init(void){…

// Send a single character to the UART transmitter
void uart_send(unsigned char ch){
    while (!(UCSR0A & (1 << UDRE0))); //wait til tx data buffer empty
    UDR0 = ch; //write the character to the USART data register
}
```



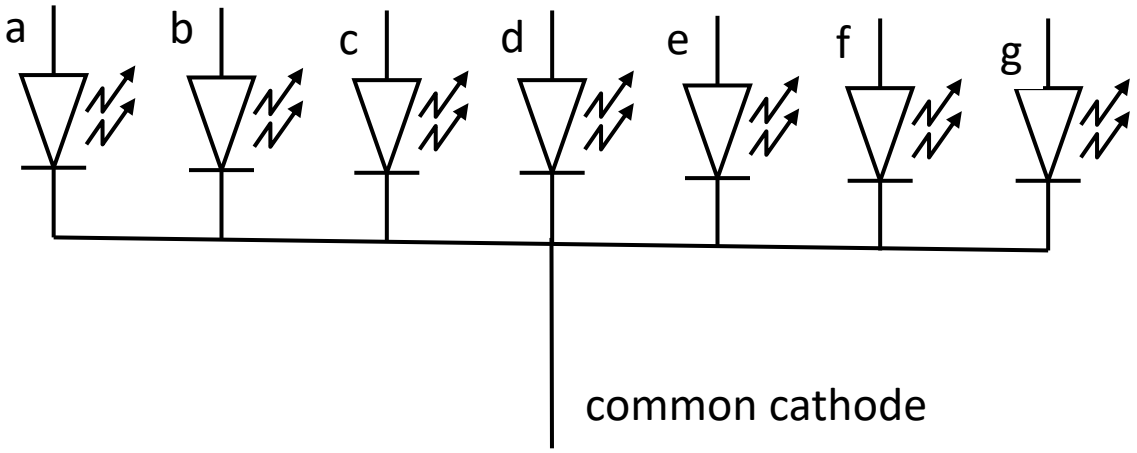
commenting out the usart_send(10); line

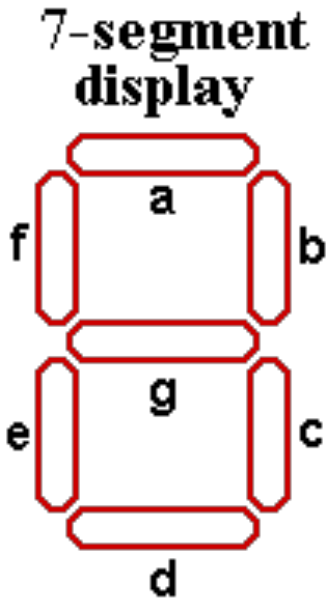


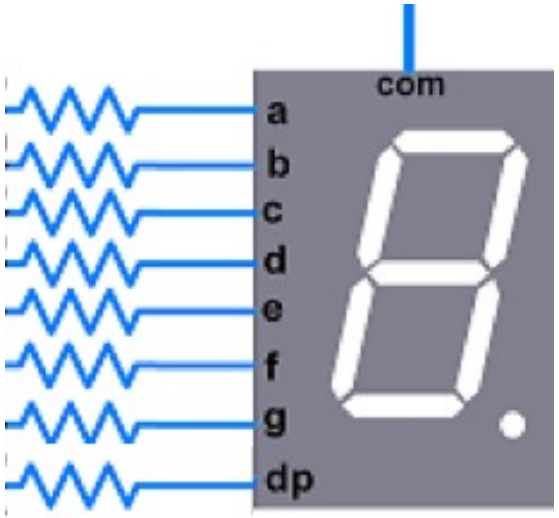
```c
/* counter_uart2.c This code implements a 0- 9999 ring counter
and displays the count value on the monitor using the UART.
Sends each count digit individually
This is a demo for ECE-231 Spring 2022
D. McLaughlin 3/18/22 */

#include <avr/io.h>     // #defines all the port pins
#include <util/delay.h> // Declares _delay_ms() function
#include <string.h>     // Declares strlen() function

void uart_init(void);
void uart_send(unsigned char);
void send_string(char *stringAddress);

int main(void){
    char digit;
    uart_init(); // initialize the USART
    while (1) {
        for (unsigned int i=0; i<10000; i++){
            digit = i/1000;         // 1000's place (most signif digit)
            uart_send(digit+'0');
            digit = (i/100) %10;    // 100's place
            uart_send(digit+'0');
            digit = (i/10) %10;     // 10's place
            uart_send(digit+'0');
            digit = i%10;           // 1's place or least significant digit
            uart_send(digit+'0');
            uart_send(13); // Carriage return (goto beginning of line)
            uart_send(10); //line feed (new line)
             _delay_ms(10);
        }
    }
}

// Send a string, char by char, to uart via uart_send()…
void send_string(char *stringAddress){…

void uart_init(void){…

void uart_send(unsigned char ch){…

/***** End of file *****/
```



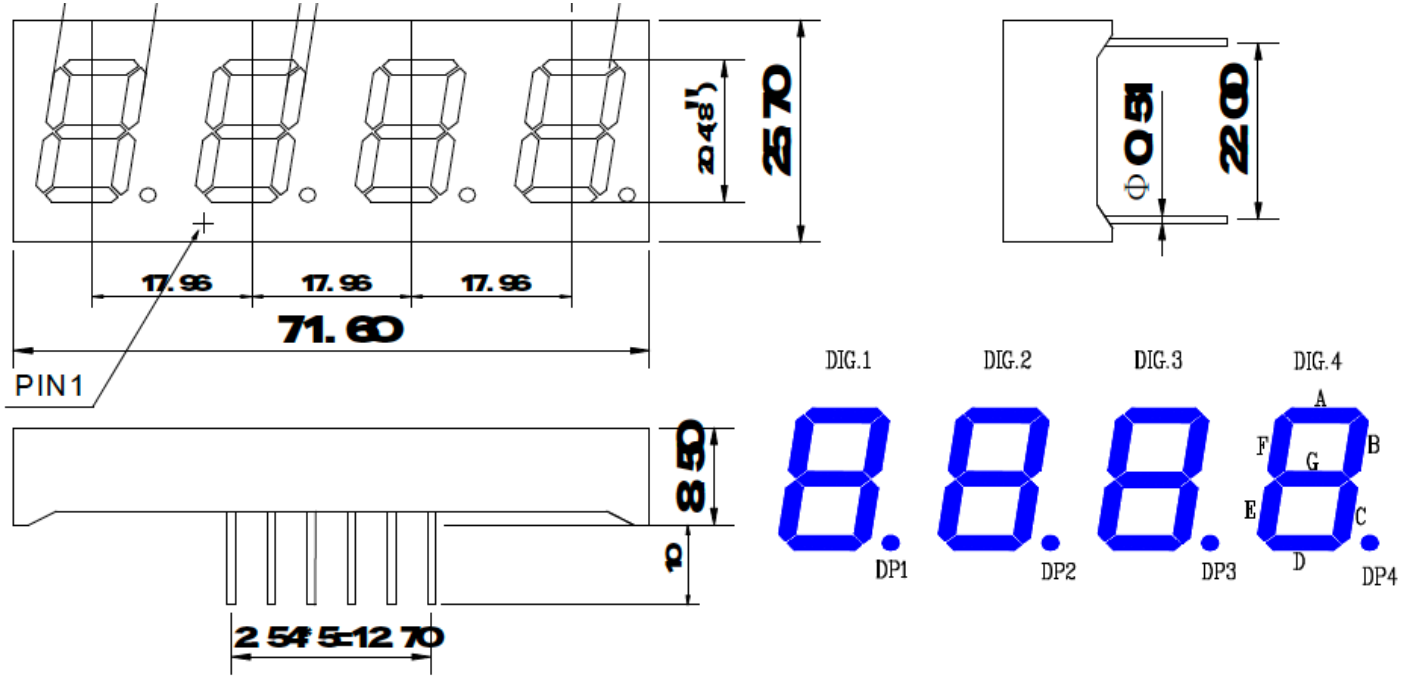
# Common Cathode 7 Segment LED

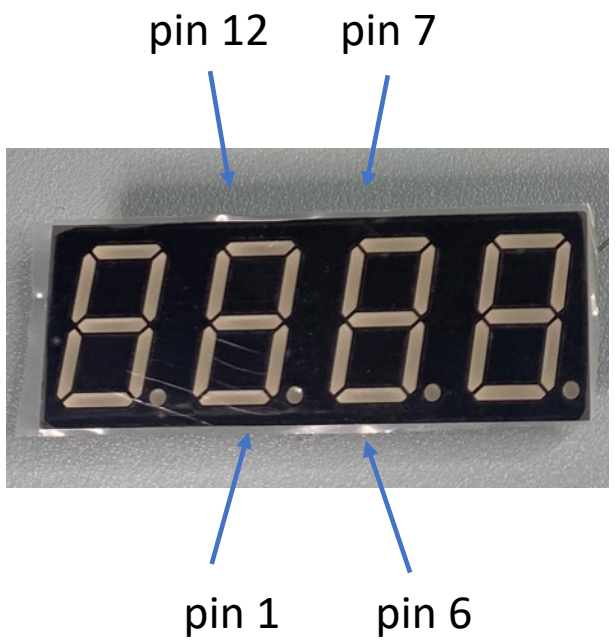


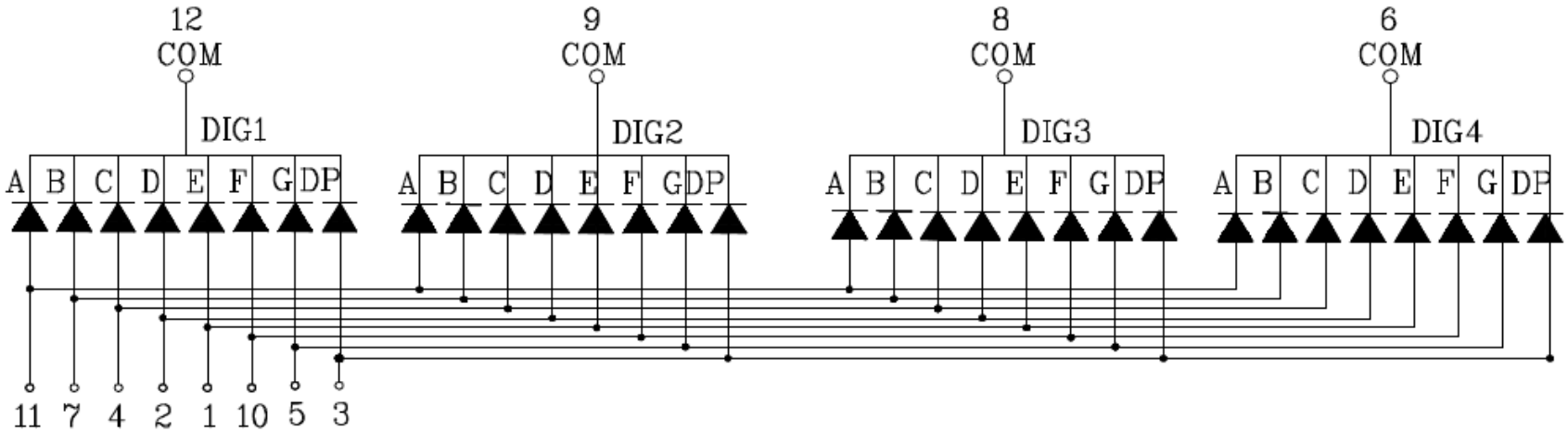



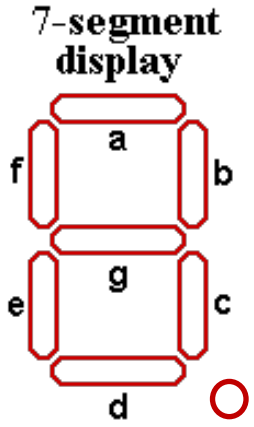

some also have a decimal point as an 8th segment

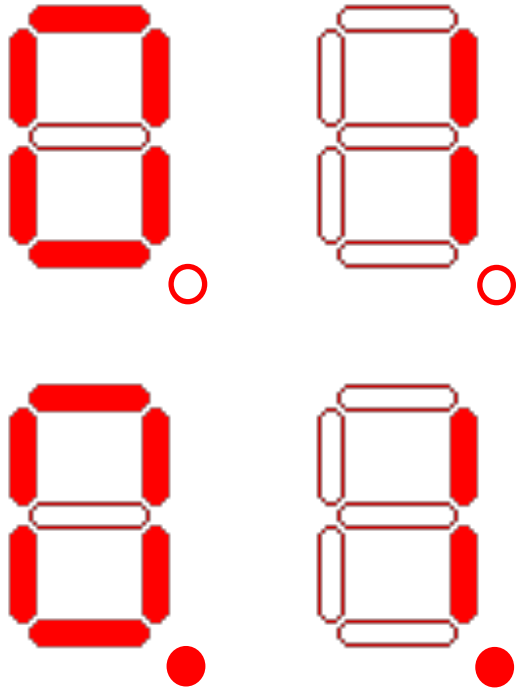


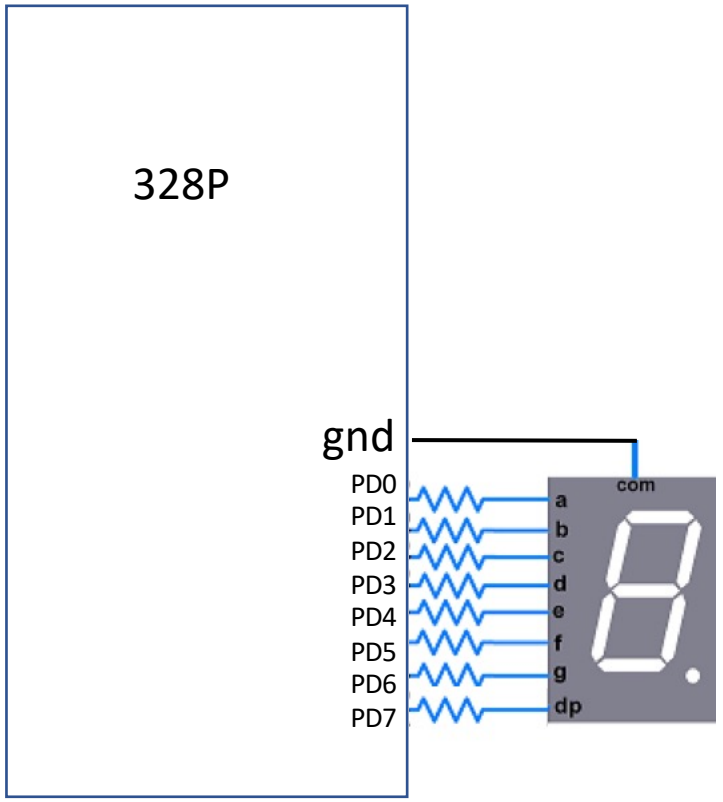




Datasheet: https://www.sparkfun.com/products/11409






Common Cathode 7 Segment LED

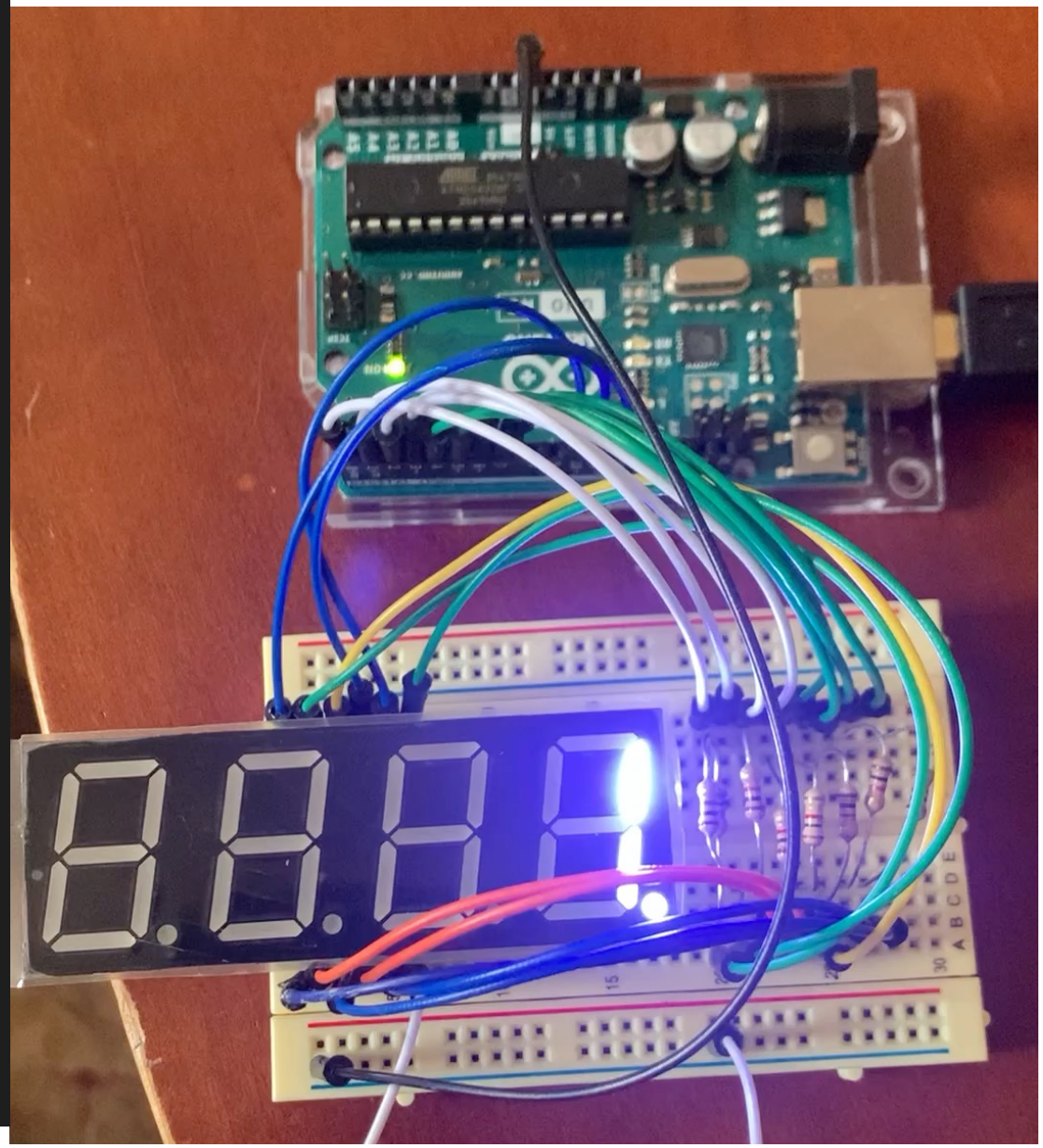
| | dp | g | f | e | d | c | b | a | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PD7 | PD6 | PD5 | PD4 | PD3 | PD2 | PD1 | PD0 | Binary | Hex |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0011 1111 | 0x3F |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0000 0110 | 0x06 |

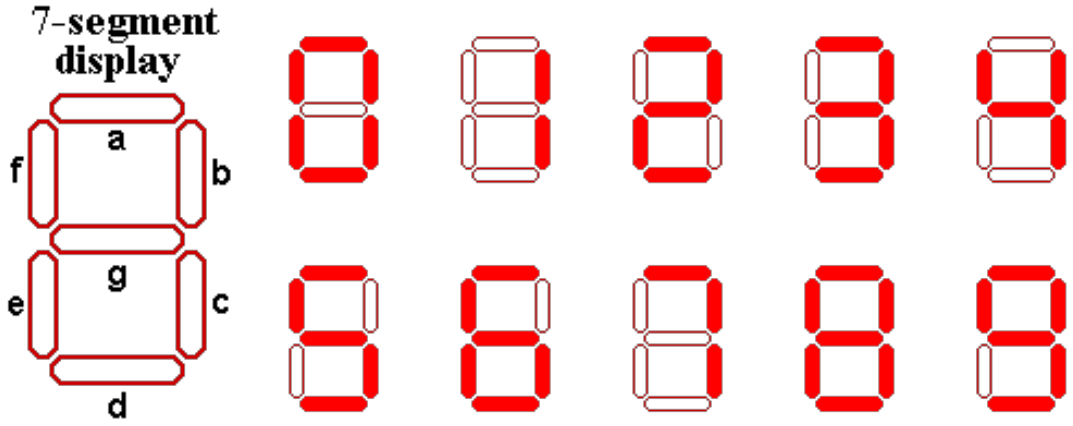
| | dp | g | f | e | d | c | b | a | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PD7 | PD6 | PD5 | PD4 | PD3 | PD2 | PD1 | PD0 | Binary | Hex |
| 0. | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1011 1111 | 0xBF |
| 1. | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1000 0110 | 0x86 |

note: these slides use ABCDEFG and abcdefg interchangably

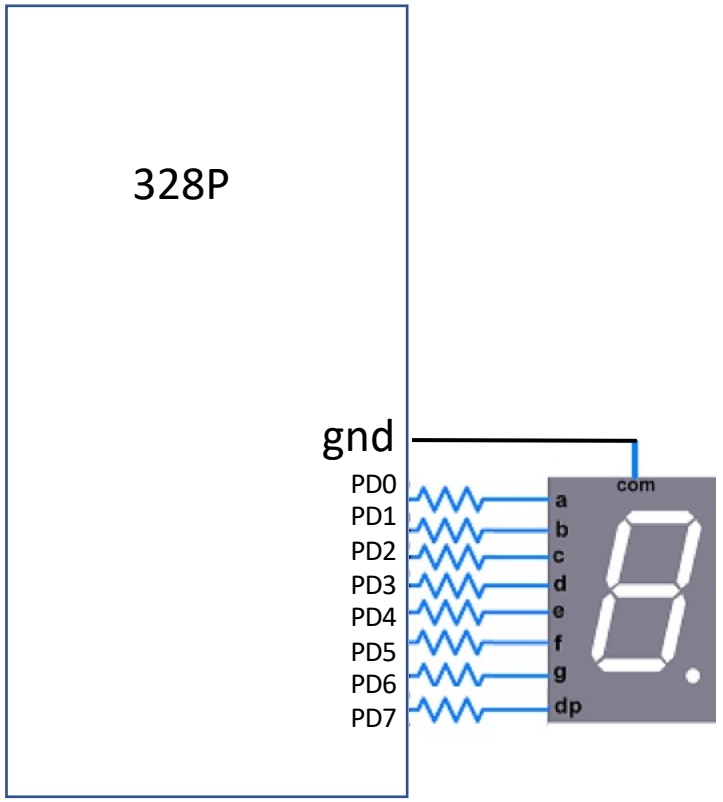
C seven_0101.c > ...

```c
/* seven_0101.c  This code displays the digits 0, 1, 0., 1.
in sequence on DIG4 of the 4 digit, 7 segment (+ dp) LED
display. This is a demo for ECE-231 Spring 2023
D. McLaughlin 3/7/23 */

#include <avr/io.h>
#include <util/delay.h>
#define MYDELAY 500

int main(void){
    DDRD = 0xFF;        // Set all 8 pins as output

    while(1){
        PORTD = 0x3f;    // Illuminate 0
        _delay_ms(MYDELAY);
        PORTD = 0x06;    // Illuminate 1
        _delay_ms(MYDELAY);
        PORTD = 0xBF;    // Illuminate 0.
        _delay_ms(MYDELAY);
        PORTD = 0x86;    // Illuminate 1.
        _delay_ms(4*MYDELAY); // Longer delay before repeating
    }
}

/*** End of File ***/
```






| | dp | g | f | e | d | c | b | a | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PD7 | PD6 | PD5 | PD4 | PD3 | PD2 | PD1 | PD0 | Binary | Hex |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0011 1111 | 0x3F |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0000 0110 | 0x06 |
| 2 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0101 1011 | 0x5B |
| 3 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0100 1111 | 0x4F |
| 4 | | | | | | | | | | |
| 5 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0110 1101 | 0x6D |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0110 1111 | 0x6F |




Common Cathode 7 Segment LED

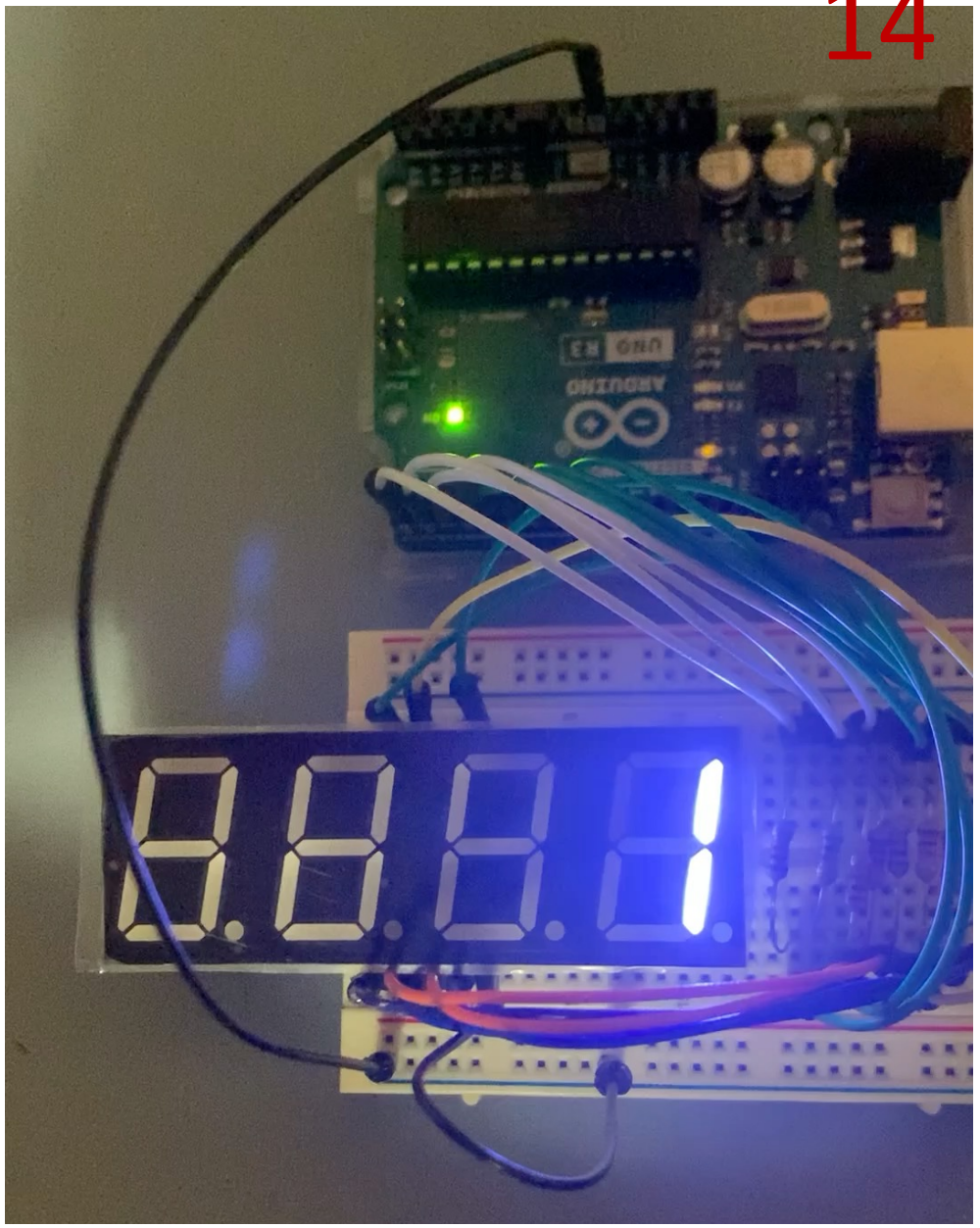
```c
/* seven_main.c  This code demonstrates the use of a 4 digit
7 segment LED.
D. McLaughlin 3/16/22 ECE-231 Demo */

#include "avr/io.h"
#include "util/delay.h"

int main(void)
{
    unsigned char ledDigits[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D,
        0x07, 0x7F, 0x67};
    unsigned char i=0;
    DDRD = 0xFF; //7segment pins

    while (1) {
        i++;
        if(i>9)
            i=0;
        PORTD = ledDigits[i]; //digit
        _delay_ms(10);
    }
}
```

for this movie,
_delay_ms(1000);



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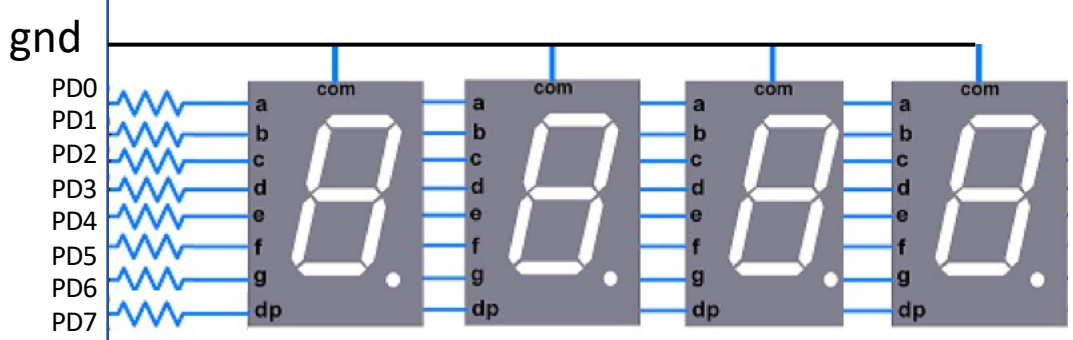
D. McLaughlin 3/16/22 ECE-231 Demo */

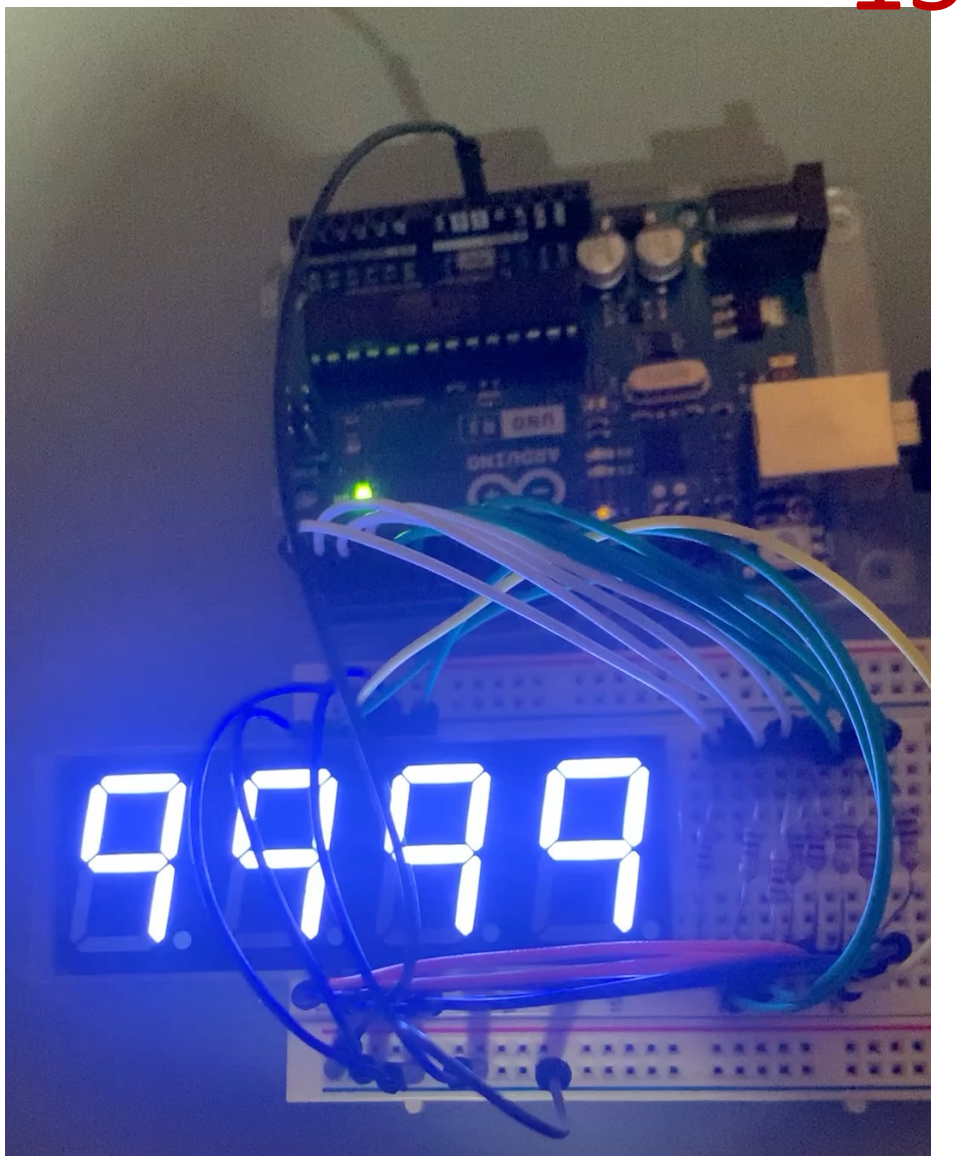
#include "avr/io.h"
#include "util/delay.h"

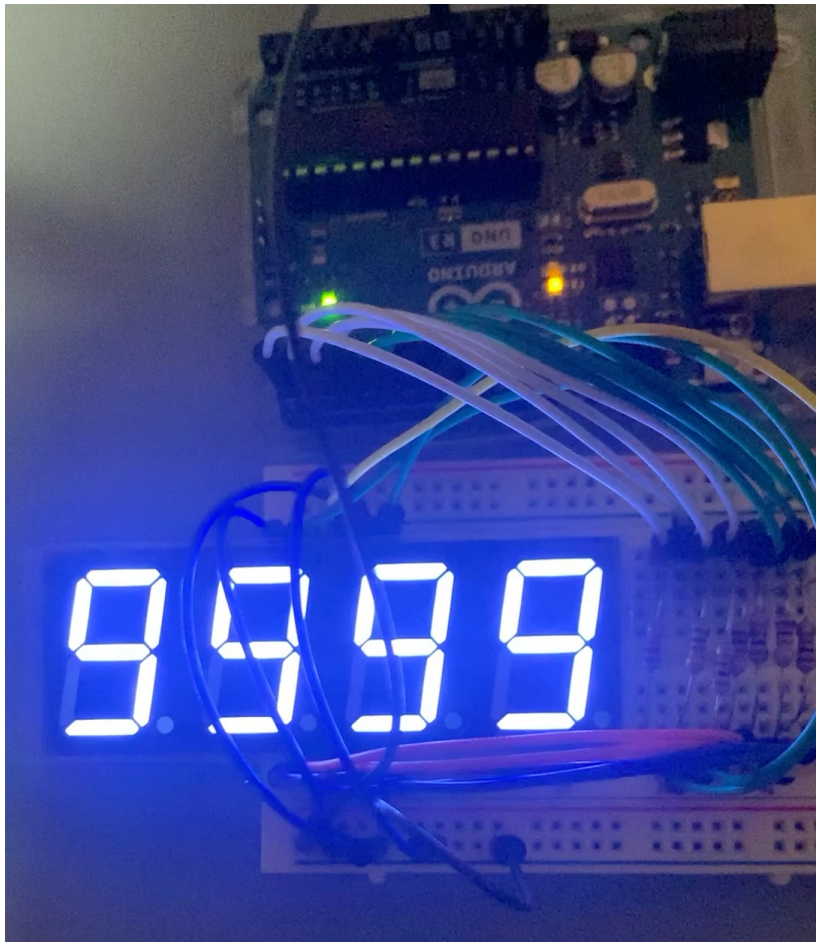
int main(void)
{
    unsigned char ledDigits[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D,
        0x07, 0x7F, 0x67};
    unsigned char i=0;
    DDRD = 0xFF; //7segment pins

    while (1) {
        i++;
        if(i>9)
            i=0;
        PORTD = ledDigits[i]; //digit
        _delay_ms(10);
    }
}
```

for this movie,
_delay_ms(1000);

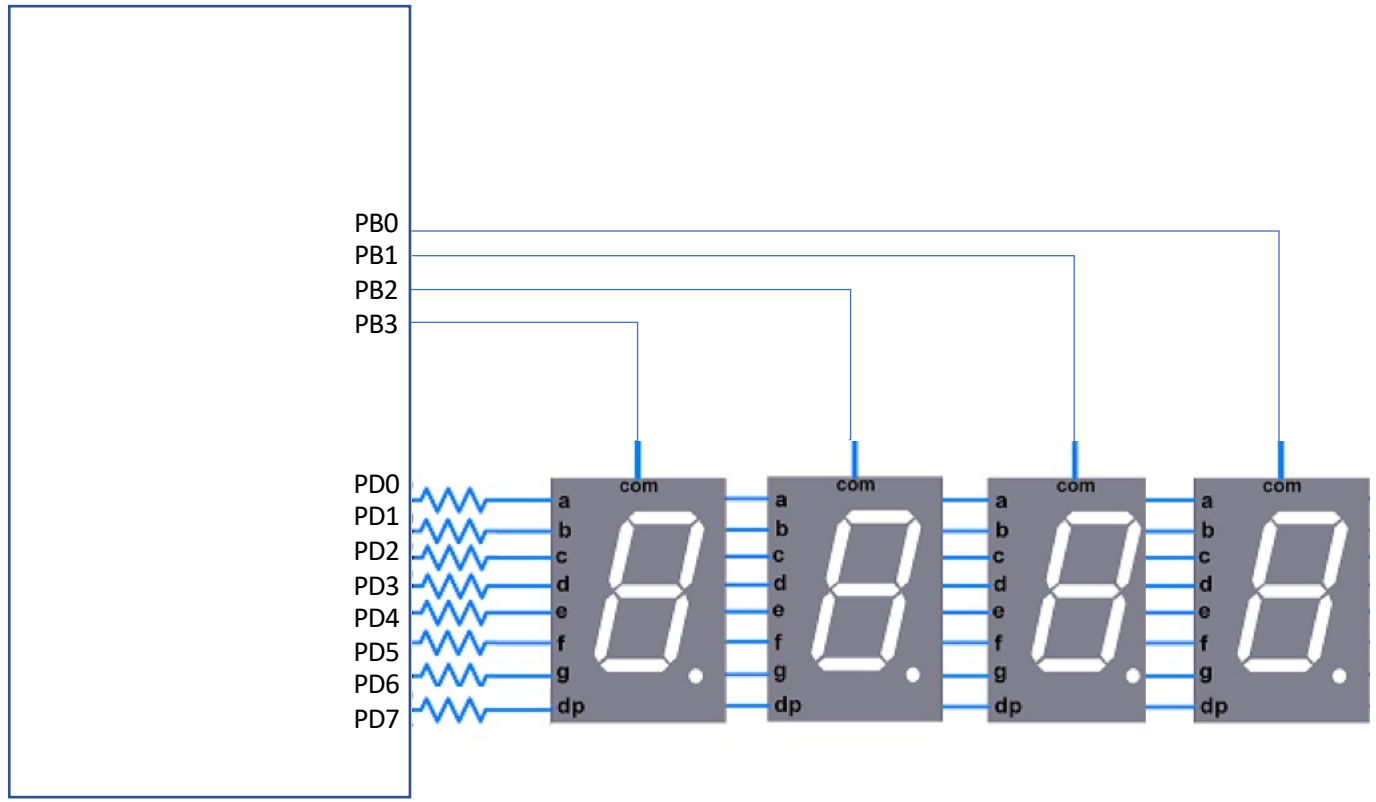


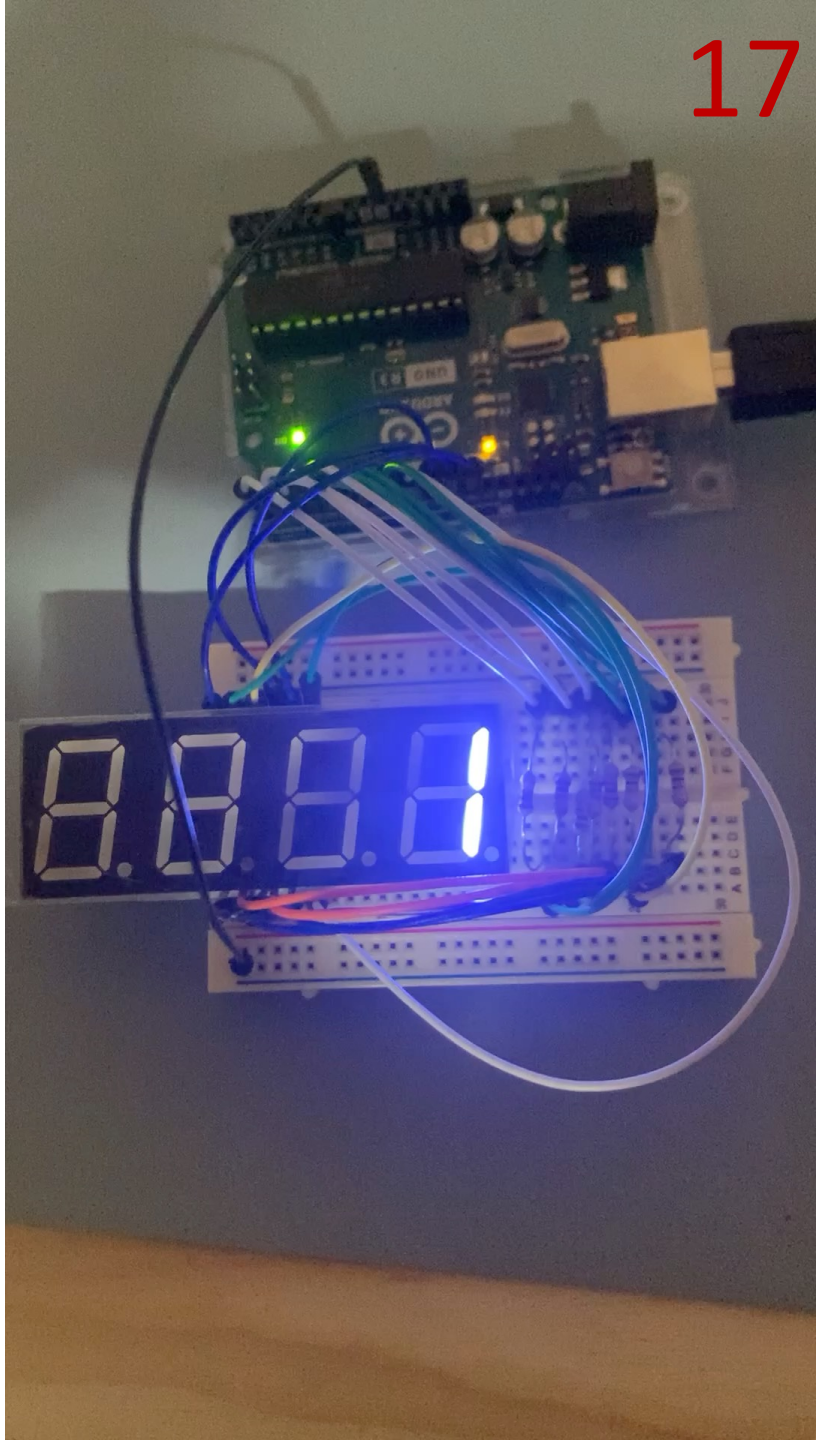




Retinal Persistence

The com pin for each digit connected to PB0-PB4.
When these pins are low, the digit will glow.
Code (not shown) sequences through PB0 – PB1 – PB2 – PB3 to sequence through the digits.



retinal persistence: repeatedly illuminate digits with update faster than 1/30 sec = 0.033 sec = 33 msec

pseudocode:

increment counter (0-9999)

illuminate 1's digit
wait 5 ms

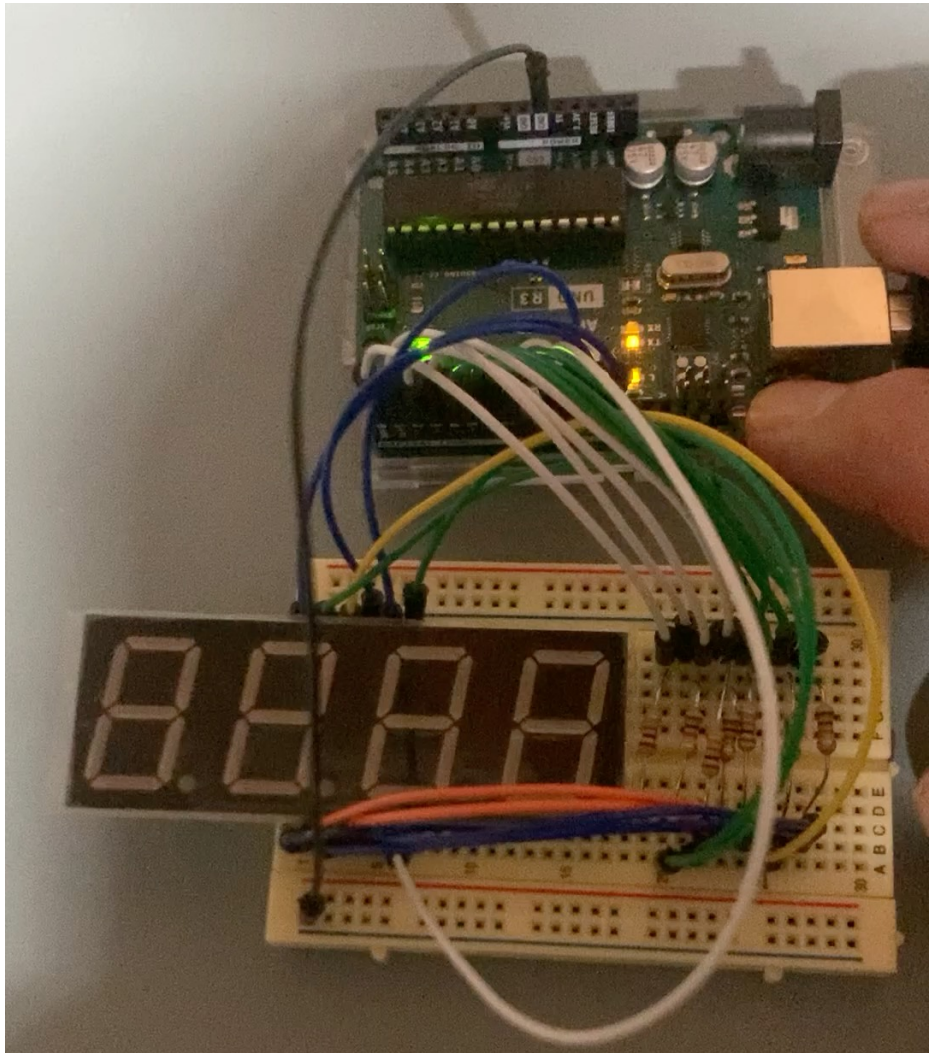
illuminate 10's digit
wait 5 ms

illuminate 100's digit
wait 5 ms

illuminate 1000's digit
wait 5 ms

repeat

this loop repeatedly illuminate each digit every 20 msec



```
/* seven_counter_main.c  This code demonstrates the use of a 4 digit
7 segment LED. This version counts 0-1000 repeatedly and uses retinal
persistence to create an always-on effect in the digits
D. McLaughlin 3/16/22 ECE-231 Demo */
```

```
#include "avr/io.h"
#include "util/delay.h"
#define PERSISTENCE 5

int main(void){

    unsigned char ledDigits[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D,
        0x07, 0x7F, 0x67};
    unsigned int i=0;
    unsigned char DIG1, DIG2, DIG3, DIG4;

    DDRD = 0xFF;    // 7segment pins
    DDRB = 0xFF;    // Digit enable pins
    PORTB = 0xFF;   // Disable all the digits initially

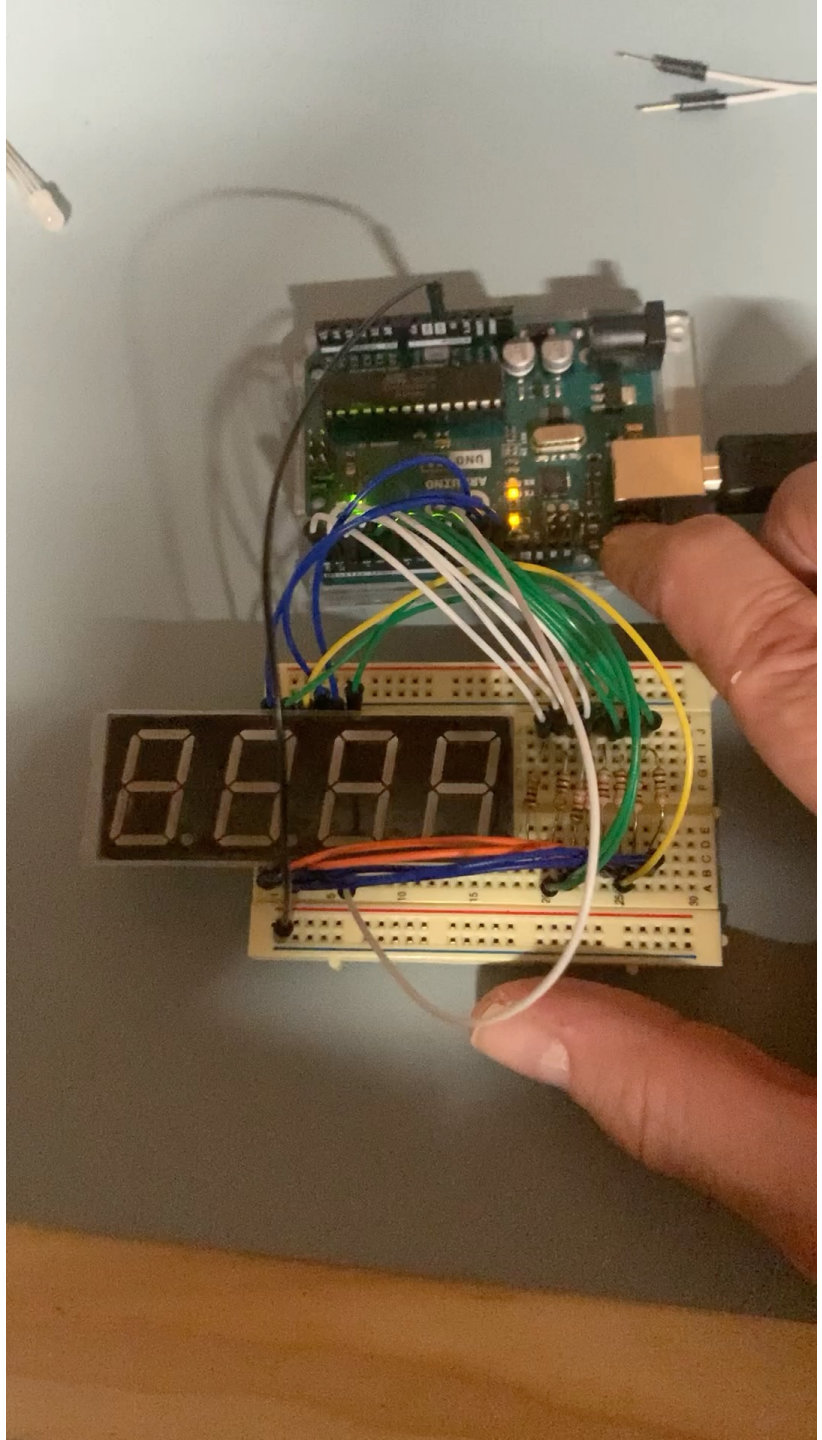
    while (1) {
        i++;
        if(i>9999) i=0;

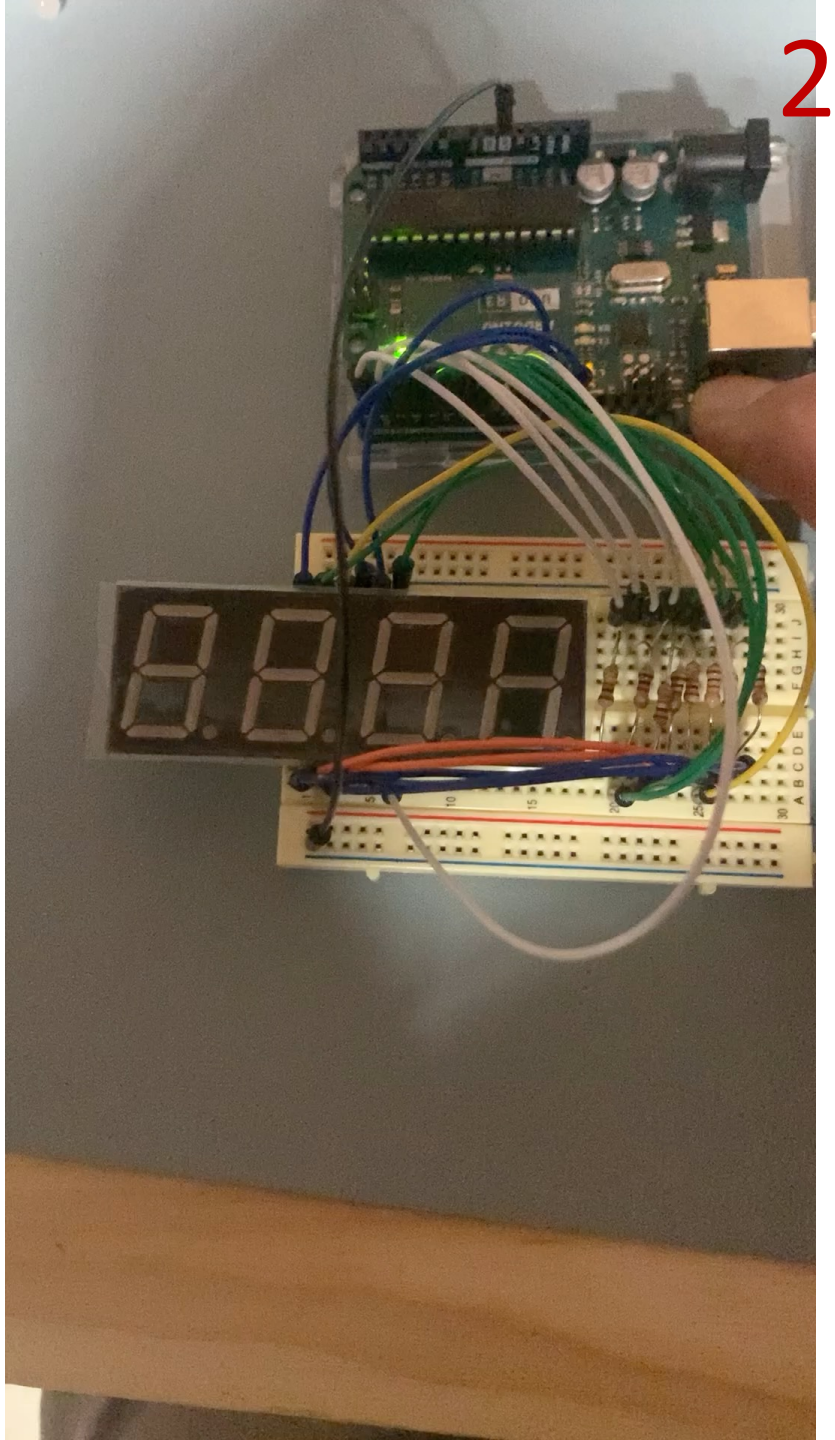
        DIG4 = i%10;                // 1's digit (Least Significant Digit)
        PORTD = ledDigits[DIG4];
        PORTB = ~ (1<<1);           // enable 1's digit (DIG4)
        _delay_ms(PERSISTENCE);     // stay on for small amount of time

        DIG3= (i/10)%10;            // 10's digit
        PORTD = ledDigits[DIG3];
        PORTB = ~ (1<<2);           // Enable 10's digit (DIG3)
        _delay_ms(PERSISTENCE);

        DIG2 = (i/100)%10;          // 100's digit
        PORTD = ledDigits[DIG2];
        PORTB = ~ (1<<3);           // Enable 100's digit (DIG2)
        _delay_ms(PERSISTENCE);

        DIG1 = (i/1000);            // 1000's digit (Most signif digit)
        PORTD = ledDigits[DIG1];
        PORTB = ~ (1<<4);           // Enable 1000's digit (DIG1)
        _delay_ms(PERSISTENCE);
    }
}
```



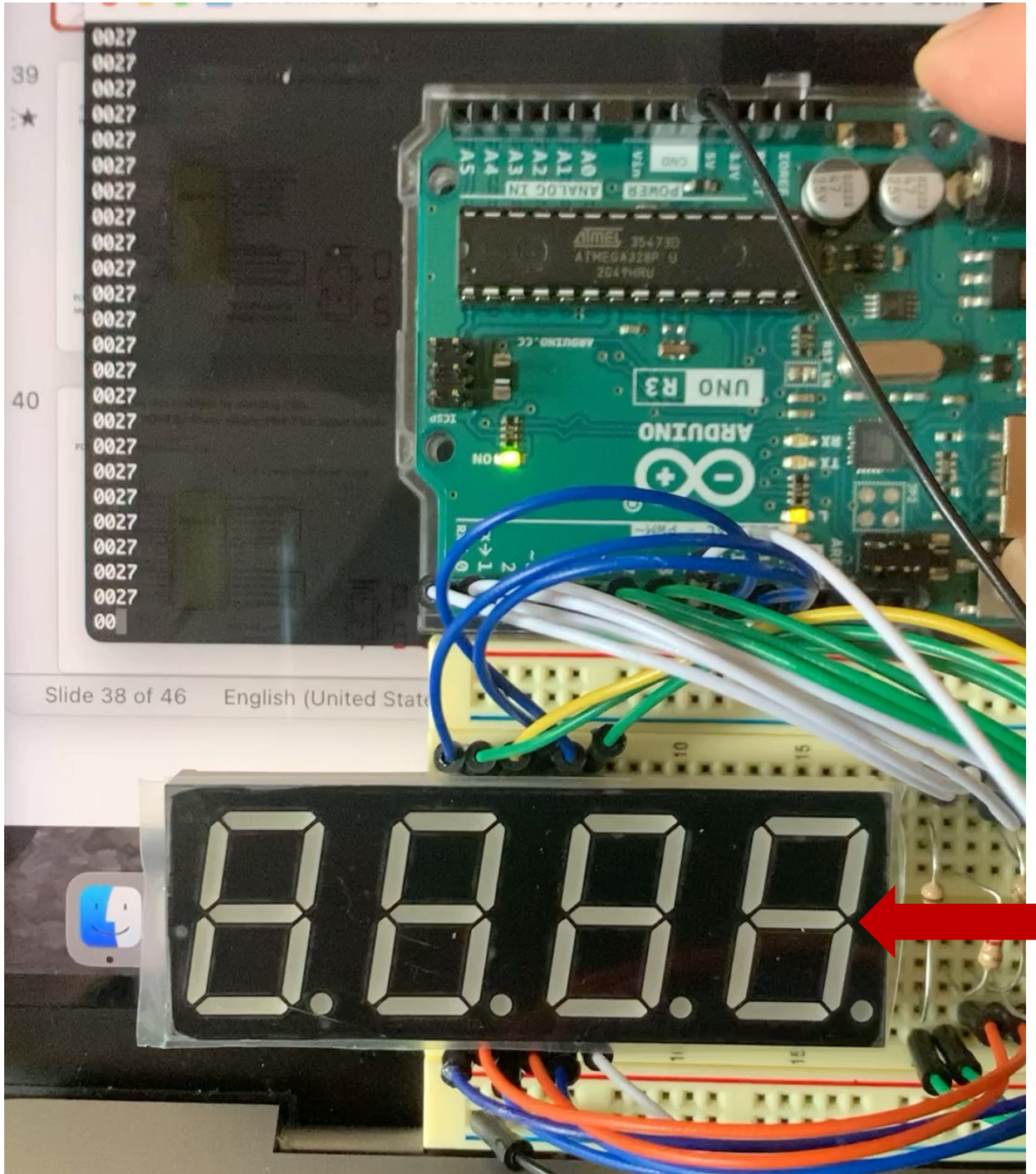


```c
/* seven_enable_main.c  This code demonstrates the use of a 4 digit
7 segment LED. This version counts 0-1000 repeatedly and uses
persistence to create an always-on effect in the digits
D. McLaughlin 3/16/22 ECE-231 Demo */

#include "avr/io.h"
#include "util/delay.h"
#define PERSISTENCE 5
#define COUNTTIME 200           // This is the # of ms beteen counts

int main(void)
{
    unsigned char ledDigits[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D,
        0x07, 0x7F, 0x67};
    unsigned int i=0;
    unsigned char DIG1, DIG2, DIG3, DIG4;

    DDRD = 0xFF; // 7segment pins
    DDRB = 0xFF; // Digit enable pins
    PORTB = 0xFF;   // Initially disable the digits
    while (1) {
        i++;
        if(i>9999) i=0;

        DIG4 = i%10;
        DIG3= (i/10)%10;
        DIG2 = (i/100)%10;
        DIG1 = (i/1000);

            for (int j=0; j<COUNTTIME/PERSISTENCE/4; j++){

                PORTD = ledDigits[DIG4];
                PORTB = ~ (1<<1);
                _delay_ms(PERSISTENCE);

                PORTD = ledDigits[DIG3];
                PORTB = ~ (1<<2);
                _delay_ms(PERSISTENCE);

                PORTD = ledDigits[DIG2];
                PORTB = ~ (1<<3);
                _delay_ms(PERSISTENCE);

                PORTD = ledDigits[DIG1];
                PORTB = ~ (1<<4);
                _delay_ms(PERSISTENCE);
            }

        }
    }
```

# This code combines UART & 4 digit 7 segment display



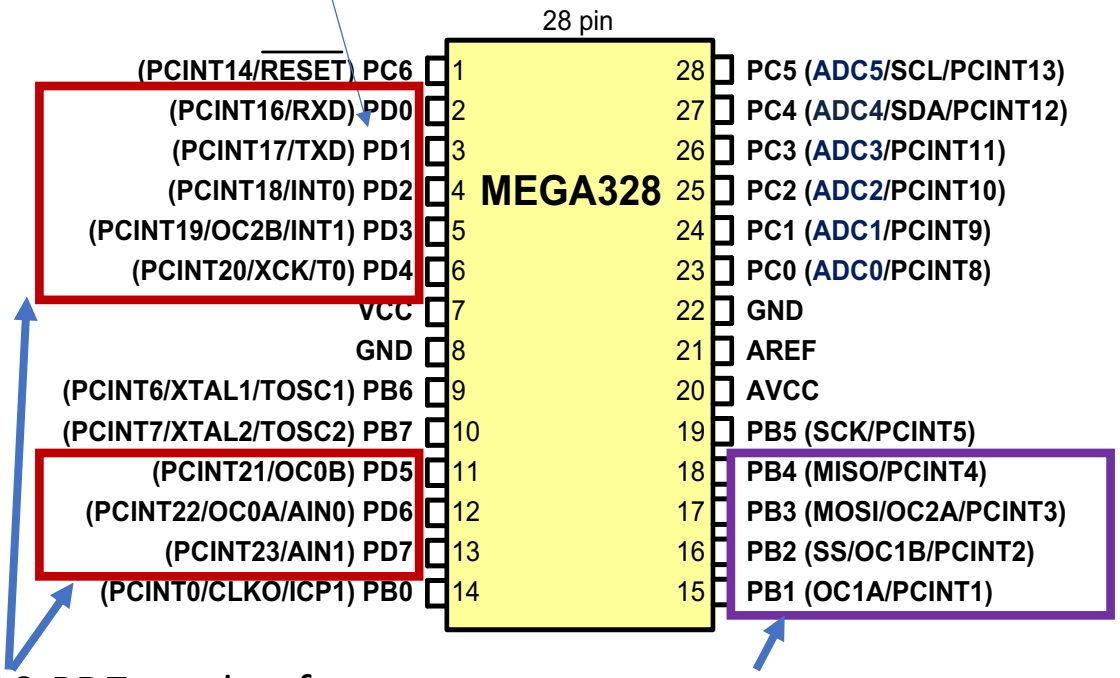
```c
/* seven_uart_main.c  This code demonstrates the use of a 4 digit
7 segment LED. This version counts 0-1000 repeatedly and uses
persistence to create an always-on effect in the digits. Digits
are also sent via UART. This code has D1 contention between UART &
the display. D. McLaughlin 3/20/22 ECE-231 Demo */

#include "avr/io.h"
#include "util/delay.h"
#define PERSISTENCE 5
#define COUNTTIME 1000          // This is the # of ms beteen counts
void uart_init(void);
void uart_send(unsigned char);

int main(void){
    unsigned char ledDigits[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D,
        0x07, 0x7F, 0x67};
    unsigned int i=0;
    unsigned char DIG1, DIG2, DIG3, DIG4;
    uart_init();
    DDRD = 0xFF;    // 7segment pins
    DDRB = 0xFF;    // Digit enable pins

    while (1) {
        i++;
        if(i>9999) i=0;

        DIG4 = i%10;                // Compute 1's digit (Least sig digit)
        DIG3= (i/10)%10;            // Compute 10's digit
        DIG2 = (i/100)%10;          // Compute 100's digit
        DIG1 = (i/1000);            // Compute 1000's digit (Most sig digit)

        for (int j=0; j<COUNTTIME/PERSISTENCE/4; j++){
            PORTD = ledDigits[DIG1];        // 1000's digit (Most significant)
            uart_send(DIG1+'0');            // Tx 1000's digit
            PORTB = ~ (1<<4);               // Enable 1000's digit
            _delay_ms(PERSISTENCE);

            PORTD = ledDigits[DIG2];        // 100's digit
            uart_send(DIG2+'0');            // Tx 100's digit
            PORTB = ~ (1<<3);               // Enable 100's digit
            _delay_ms(PERSISTENCE);

            PORTD = ledDigits[DIG3];        // 10's digit
            uart_send(DIG3+'0');            // Tx 10's digit
            PORTB = ~ (1<<2);               // Enable 10's digit
            _delay_ms(PERSISTENCE);

            PORTD = ledDigits[DIG4];        // 1's digit (Lease sig digit)
            uart_send(DIG4+'0');            // Tx 1's digit
            PORTB = ~ (1<<1);               // Enable 1's digit
            _delay_ms(PERSISTENCE);

            PORTB = 0xFF;                   // Disable all digits

            uart_send(13); // Carriage return (goto beginning of line)
            uart_send(10); //line feed (new line)
        }
    }
}

void uart_init(void){…

void uart_send(unsigned char ch){…
```




pay attention to
LED segment b

# GPIO PORTD & USART wire contention

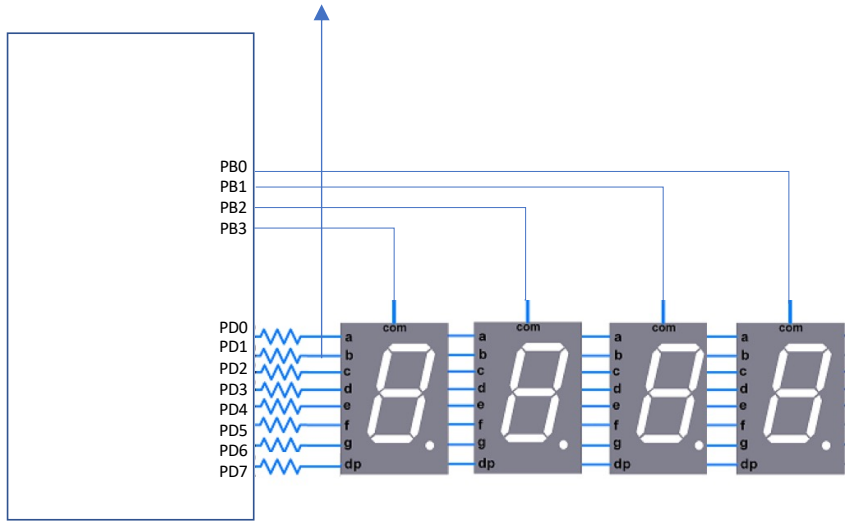
TXD (USART) uses same wire as PD1
(wired to segment b of the display)

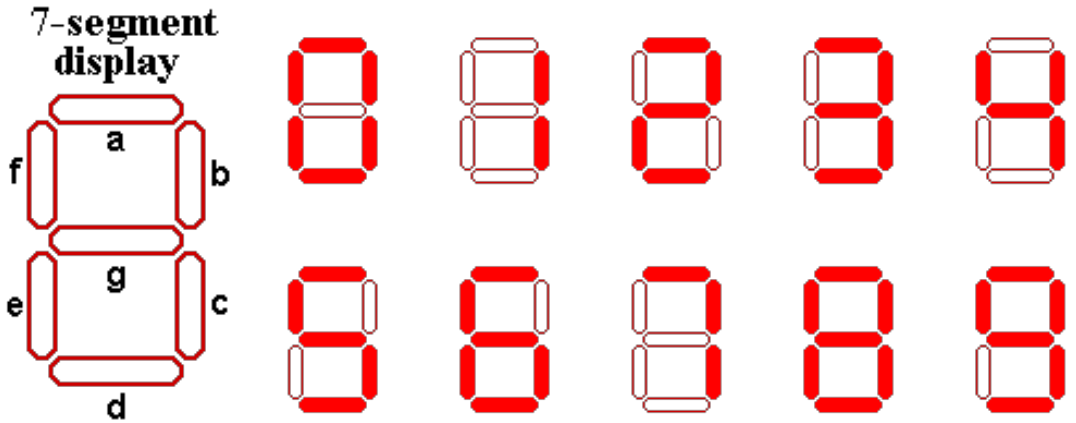



PD0-PD7 used to for
segments a-g & dp

PB1-PB4 used to
enable DIG1-DIG4

TXD from UART to
UART/USB converter

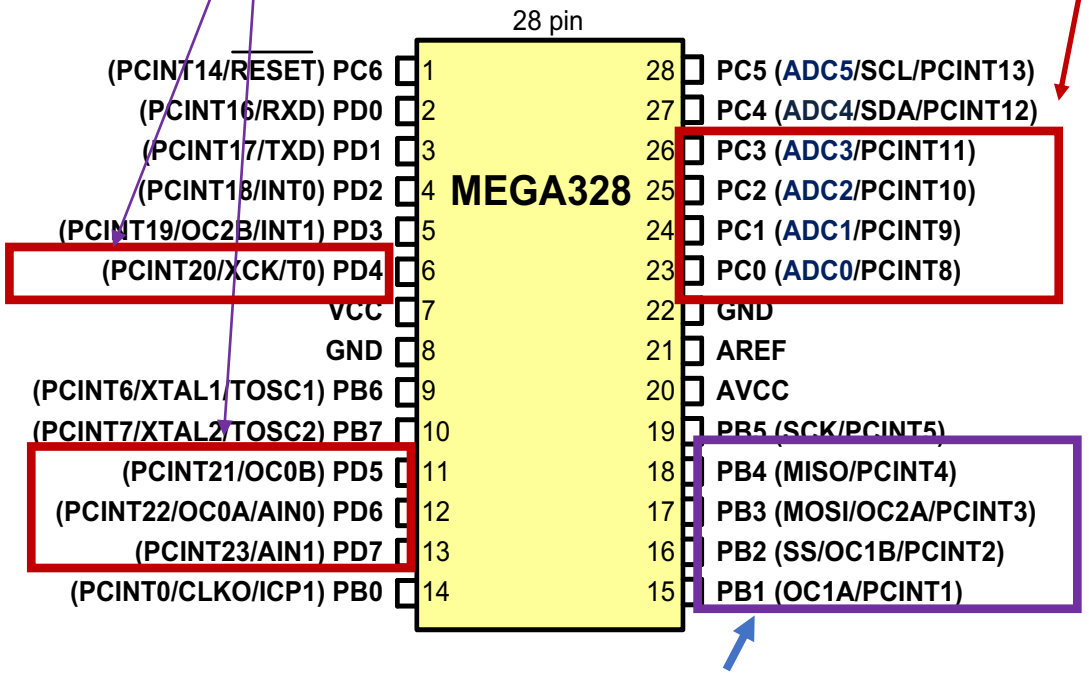


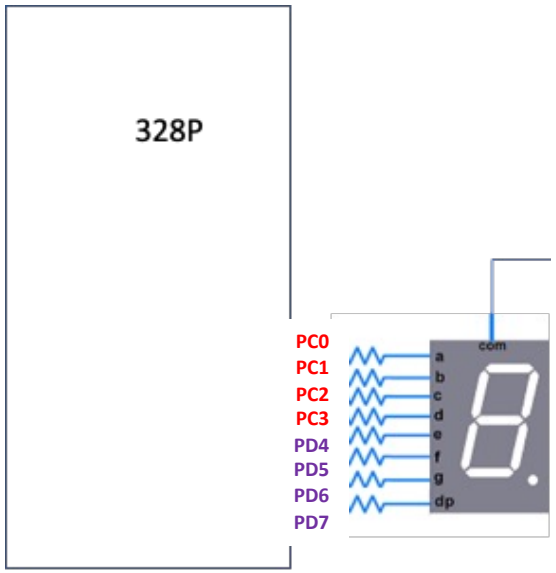
# Solve this problem by avoiding PD0.
# Use PC0-3 for lower nibble; PD4-7 for upper nibble

PD4-PD7 upper nibble (upper 4 bits)

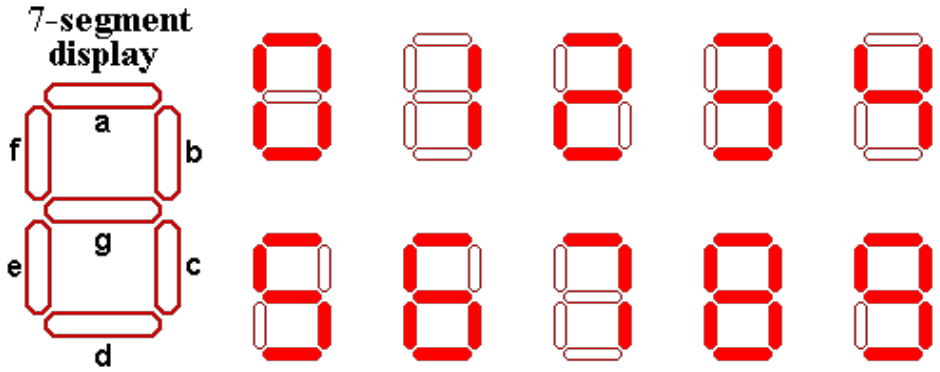
PC0-PC3 lower nibble (lower 4 bits)



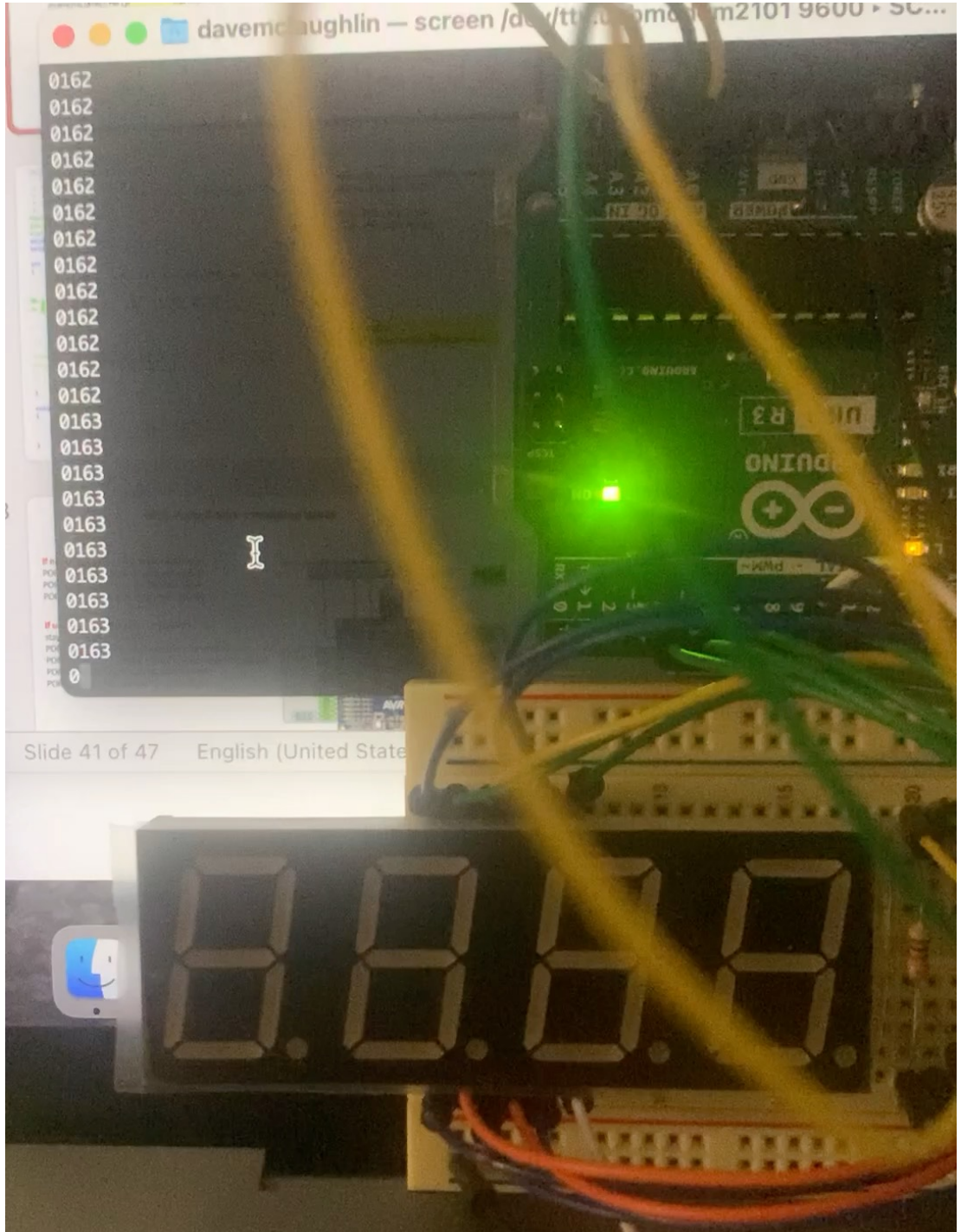

PB1-PB4 used to enable DIG1-DIG4




Common Cathode 7 Segment LED



```c
/* seven_uart_corrected.c  Demonstrates simultaneous display
of a 4 digit ring counter (0000-9999) to UART & 4 digit, 7
segment LED. PC0-3 & PD4-7 used for segments a-d, e-dp.
D. McLaughlin 3/19/22 ECE-231 Demo */

#include "avr/io.h"
#include "util/delay.h"
#define PERSISTENCE 5
#define COUNTTIME 50          // # ms between counts
void uart_init(void);
void uart_send(unsigned char);

int main(void){
    unsigned char ledDigits[] = {0x3F, 0x06, 0x5B, 0x4F, 0x66, 0x6D, 0x7D,
        0x07, 0x7F, 0x67};
    unsigned int i=0;
    unsigned char DIG1, DIG2, DIG3, DIG4;
    uart_init();    // Initialize the UART
    DDRC = 0x0F;    // Segments a-d use PC0-PC3
    DDRD = 0xF0;    // Segments e-g & dp  use PD4-PD7
    DDRB = 0xFF;    // Digit enable pins

    while (1) {
        i++;
        if(i>9999) i=0;

        DIG4 = i%10;        // 1's digit (least significant digit)
        DIG3= (i/10)%10;    // 10's digit
        DIG2 = (i/100)%10;  // 100's digit
        DIG1 = (i/1000);    // 1000's digit (most significant digit)

        for (int j=0; j<COUNTTIME/PERSISTENCE/4; j++){

            // Show 1000's digit
            PORTC = ledDigits[DIG1];
            PORTD = ledDigits[DIG1];
            uart_send(DIG1+'0');                // Tx 1000's digit
            PORTB = ~ (1<<4);                   // Enable DIG1
            _delay_ms(PERSISTENCE);

            // Show 100's digit
            PORTC = ledDigits[DIG2];
            PORTD = ledDigits[DIG2];
            uart_send(DIG2+'0');                // Tx 100's digit
            PORTB = ~ (1<<3);                   // Enable DIG2
            _delay_ms(PERSISTENCE);

            // Show 10's digit
            PORTC = ledDigits[DIG3];
            PORTD = ledDigits[DIG3];
            uart_send(DIG3+'0');                // Tx 100's digit
            PORTB = ~ (1<<2);                   // Enable DIG3
            _delay_ms(PERSISTENCE);

            // Show 1's digit
            PORTC = ledDigits[DIG4];
            PORTD = ledDigits[DIG4];
            uart_send(DIG4+'0');                // Tx 10's digit
            PORTB = ~ (1<<1);                   // Enable DIG4
            _delay_ms(PERSISTENCE);

            PORTB = 0xFF;                       // Disable all digits
            uart_send(13);                      // Tx carriage return
            uart_send(10);                      // Tx line feed
        }
    }
}

void uart_init(void){…

void uart_send(unsigned char ch){…
```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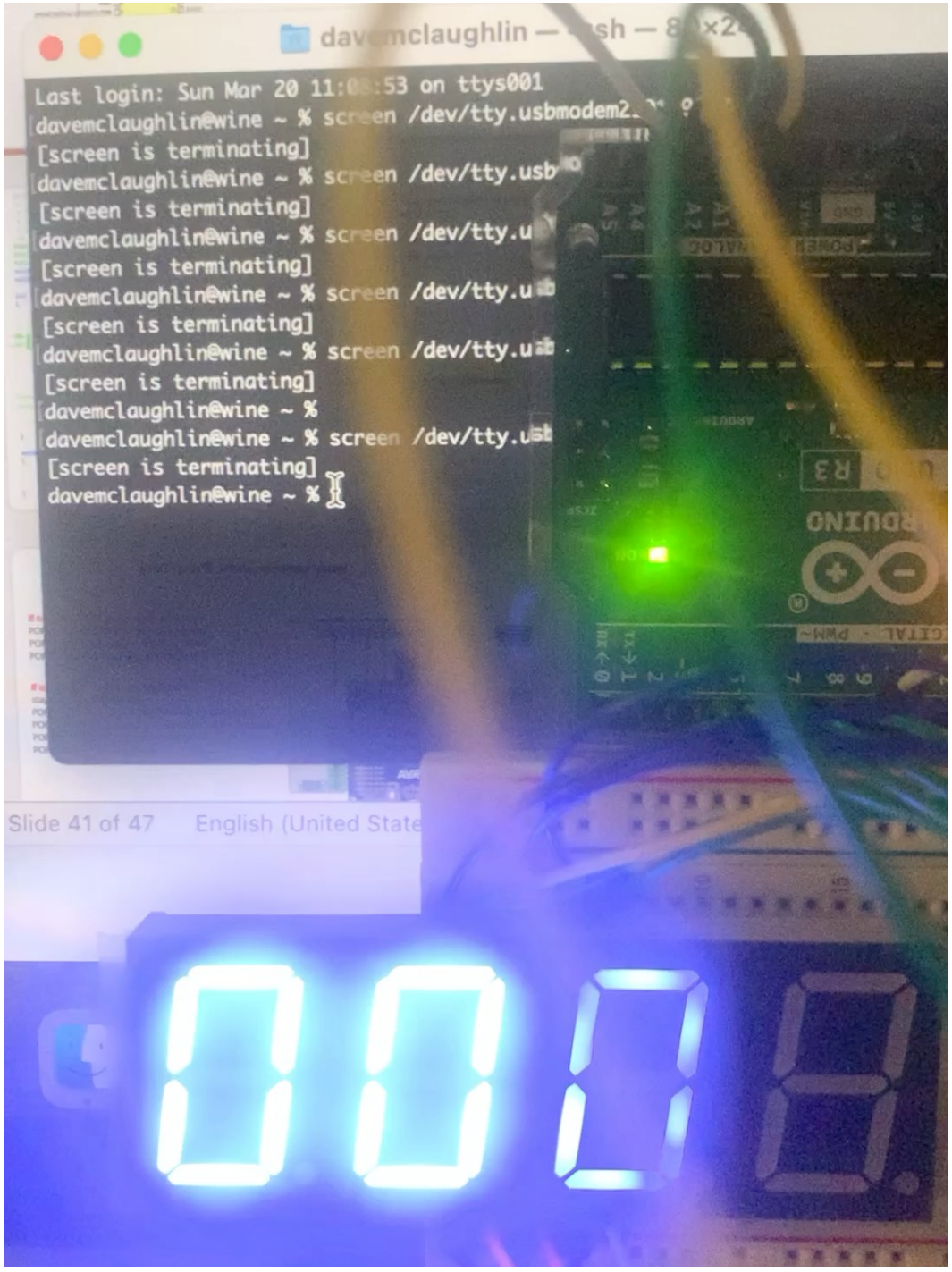
Last login: Sun Mar 20 11:08:53 on ttys001
davemclaughlin@wine ~ % screen /dev/tty.usbmodem2
[screen is terminating]
davemclaughlin@wine ~ % screen /dev/tty.usb
[screen is terminating]
davemclaughlin@wine ~ % screen /dev/tty.u
[screen is terminating]
davemclaughlin@wine ~ % screen /dev/tty.u
[screen is terminating]
davemclaughlin@wine ~ % screen /dev/tty.u
[screen is terminating]
davemclaughlin@wine ~ %
davemclaughlin@wine ~ % screen /dev/tty.us
[screen is terminating]
davemclaughlin@wine ~ %
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