TB029

Complementary LED Drive

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INTRODUCTION

Light Emitting Diodes, or LED's, are discrete components able to produce light when a current passes through them. Most microcontroller designs use one or more LED's. This application highlights the utility of driving multiple LED's with a minimum number of I/O pins. Typically, each I/O drives or sources a single LED. To drive more than one, a high I/O count is required. In order to reduce I/O requirements, LED's are multiplexed in a matrix (as found on a keyboard). The complementary LED drive method proposes to implement even more LEDs while using fewer I/O.

LEDs are polarized and can only operate when current flows from anode to cathode (unlike a switch). We can therefore take advantage of this fact. Table 1 shows the number of possible LEDs with respect to the number of I/O pins required. Fifty-six LEDs can be driven using only 8 pins. The only drawback is that only one LED can be driven at a time.

Typical applications include; games, bargraphs, audio, video, or driving a single seven-segment LED display.

TABLE 1 NUMBER OF LEDS WITH RESPECT TO I/O COUNT

I/O pins	2	3	4	5	6	6	8
LEDs	2	6	12	20	30	42	56

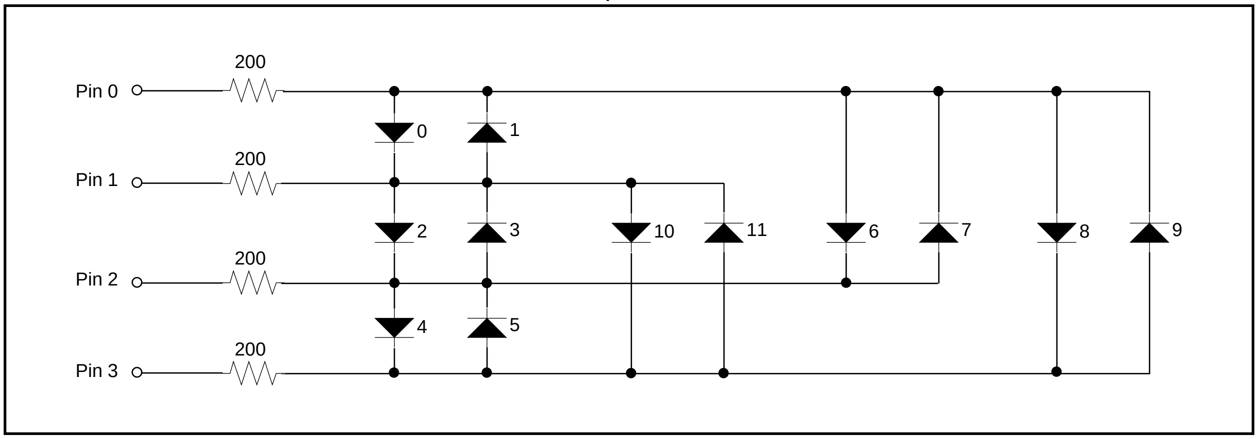
THEORY OF OPERATION

Some microcontrollers available today can sink high current, while others offer a limited number of pins to source high current. Microchip microcontrollers have a very flexible pin structure. When a pin is configured as an input, the input impedance is very high (typically 10 Mohm). When a pin is configured as an output, it can source 20 or 25 mA and sink 25 mA.

To have a better understanding of the application, place two diodes in parallel and reverse the polarities (that is, attach anode to cathode and vice-versa). If you apply 5 volts (with of course a limiting resistor) to one end and ground to another, only one LED will illuminate. The reason is, LED's are polarized and can operate only when current flows from anode to cathode.

Figure 1 gives an example of driving 12 LEDs using only 4 I/Os. To turn an LED on, first configure the appropriate register determining which pins are inputs and which are outputs. Then, write the appropriate voltages on the output pins. Each pin has a 200 ohm resistor to limit the current through the LED's, and since two pins are needed to drive one LED, the resistance is doubled.

FIGURE 1: EXAMPLE OF LED PLACEMENT, RESULTING IN 12 LEDS FOR 4 PINS



There will always be numerous paths for the current to travel between two pins with this technique. Let's take LED 6 for instance (pin 0 and pin 2 configured as outputs, pin 1 and pin 3 configured as inputs; pin 0 is at 5 Vcc and pin 2 is at ground). There are three distinct paths that the current can take:

- Through LED 6
- Through LED 0 in series with LED 2
- Through LED 8 in series with LED 5

Only LED 6 will light up because all three paths have the same voltage drop and all LED's in the series do not have enough of a voltage drop to drive any current.

SPECIAL CONSIDERATIONS

The Complementary LED Drive technique will not work with an open collector output (for example pin RA4 on the PIC16CXX family). Care should be taken when sharing a port with other I/O functions, use a shadow register as a port buffer. Do all operations on the shadow register and write this buffer to the port. It is possible to drive more than one LED at a time, but care must be given in the design. For example, in Figure 1, LEDs 0 and 8 will work if pin 0 (Vcc), pin 1 (Gnd) and pin3 (Gnd) are outputs and pin 2 is an input.

MULTIPLE LEDs AT THE SAME TIME

Trying to turn on more than one LED at a time is a recurrent problem since the Complementary LED Drive technique only allows one LED at a time to be driven. The solution is to have a duty cycle scheme where each LED is turned on sequentially (4 LED's produce a 25% duty cycle). However, there is concern that this process will diminish the brightness level.

Normally, as we increase current flow through an LED, it's brightness increases until it reaches a point where the brightness will actually decrease. This is due to the anode-cathode junction overheating. By running short pulses through the LED at a higher current, we are able to minimize the overheating, and the peak luminosity increases (phenomenon used in GaAsP lasers). For instance, a 10 mA LED has the same intensity to a photometer as a 40 mA pulsed LED with a 25% duty cycle. Both instances produce the same luminosity when measureing the luminosity with a photometer.

Fortunately, the human eye doesn't act as a photometer. It can only combine the average brightness and peak brightness. Our earlier 40 mA example will therefore appear brighter than the 10 mA LED. To increase the current at the maximum rated value of the Microchip microcontroller, use the 25 mA sink/source capability. This pulsing technique is quite useful in battery applications. By pulsing a higher current with a smaller duty cycle, the visual brightness is maintained while consuming less power.

Certain precautions must be taken to use the pulsating technique. First, make sure the LED junction does not overheat, and second, do not dissipate more than the average maximum rated power of the LED.

To learn more about the LED properties in a multiplexed environment, please refer to Siemens Optoelectronics Data Book 1995-1996, Multiplexing LED Displays, Appnote3, p.11-10.

SOFTWARE

As complex as the hardware appears, the software is quite straight forward. Just clear all I/Os associated with the LEDs to remove all glitches. Then load the offset into the accumulator and call a table that configures the I/O TRIS register. Remember that pins configured as outputs will either source (anode of the selected LED) or sink (cathode of the selected LED) current, and all other pins will be configured as inputs. At this point, use the same offset to call a table with the appropriate voltages.

The code is a simple subroutine written for a PIC16C54. Figure 1 is located on PORTA, and a 200 ohm resistor is added for each pin.

CONCLUSION

The Complementary LED Drive will help minimize the number of pins required to drive LEDs in your design, thereby taking advantage of Microchip Technology’s smaller 8-pin families.

APPENDIX A: SOFTWARE LISTING

```
Output_Led_
     clrf      PORTA           ; Clear port all to 0
     movf      Led_Value,w     ; Read LED pointer
     call      Table_Tris_     ; Configure i/o direction
     trisa                     ; Write to tris register
     movf      Led_Value,w     ; Read LED pointer
     call      Table_Io_       ; Call table
     movwf     PORTA           ; Write to port
     retlw     0

Table_Io_
     addwf     PCL,f
     retlw     b'00100000'     ; Led 0
     retlw     b'00000010'     ; Led 1
     retlw     b'00100000'     ; Led 2
     retlw     b'00000001'     ; Led 3
     retlw     b'00000010'     ; Led 4
     retlw     b'01000000'     ; Led 5
     retlw     b'00000001'     ; Led 6
     retlw     b'00100000'     ; Led 7
     retlw     b'00000010'     ; Led 8
     retlw     b'00100000'     ; Led 9
     retlw     b'00000001'     ; Led 10
     retlw     b'00000010'     ; Led 11
;
Table_Tris_
     addwf     PCL,f
     retlw     b'01000101'     ; Led 0
     retlw     b'01000101'     ; Led 1
     retlw     b'00000111'     ; Led 2
     retlw     b'01000110'     ; Led 3
     retlw     b'00100101'     ; Led 4
     retlw     b'00100101'     ; Led 5
     retlw     b'00100110'     ; Led 6
     retlw     b'01000101'     ; Led 7
     retlw     b'01000101'     ; Led 8
     retlw     b'00000111'     ; Led 9
     retlw     b'01000110'     ; Led 10
     retlw     b'00100101'     ; Led 11
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