AN234

Hardware Techniques for PICmicro® Microcontrollers

Author: *Joseph Julicher*
Microchip Technology Inc.

INTRODUCTION

It is the responsibility of engineers to get the most performance and capability out of the resources available. In this application note, we present ideas that have helped previous designs reduce size and cost.

This application note looks at different ways of:

- saving input pins
- driving multiple LEDs
- saving output pins
- maximizing pin usage
- power saving tricks

SAVING INPUT PINS

Multiple Switches on a Single Input

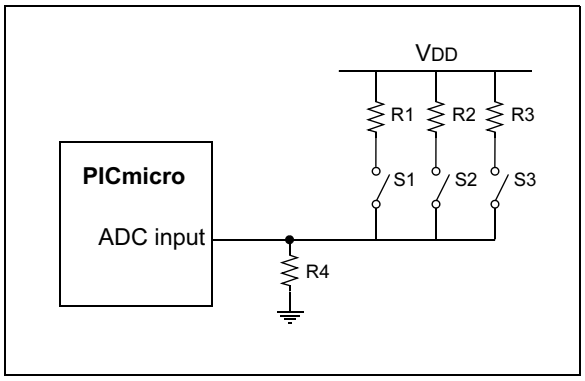
Some designs connect one switch to a single input while others use keypad style multiplexing to get multiple switches on fewer inputs. However, some designs are able to get many switches on one input. This technique requires you to change the switch problem from digital-to-analog. Once this change has been made, we can measure the analog signals with the digital microcontroller.

ANALOG-TO-DIGITAL CONVERTER (ADC)

If your microcontroller has an extra ADC input available, the ADC can be used to detect one or more switch closings by using a few resistors. See Figure 1.

By using a switched resistor network, the value of a voltage divider can be changed. The voltage is then measured with the ADC. Using simple code, the switch value is determined. One downside of this design is detecting combinations of switches. To detect combinations, the resistors have to be chosen so that the voltage resulting from a switch combination is unique.

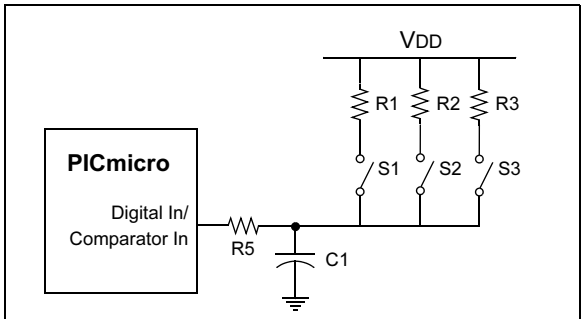
FIGURE 1: MULTIPLE SWITCHES WITH ADC



COMPARATOR AND TIMING

A comparator can be used to detect multiple switches on a single line. If the resistor values are selected appropriately then the internal voltage reference could be adjusted to find the pressed switches. By making a small change to the circuit, two additional methods become possible. We can add enough circuitry to use the comparator as an ADC and then use the method presented above, or we can change the circuit slightly and charge a capacitor. See Figure 2.

FIGURE 2: MULTIPLE SWITCHES WITH CHARGE TIMING



Note: R5 is approximately 100 Ω.

© 2003 Microchip Technology Inc.

As Figure 2 shows, R4 has been changed to a capacitor (C1). Instead of measuring voltage, we are now measuring the time it takes the capacitor to charge. Again, care must be taken to ensure that the capacitor charge time is reasonable. If the timing is too fast, the microcontroller could miss the event. If it is too slow, it will take all day to process the switch inputs. The resistor values should be chosen to provide enough gap in charge times so that each switch or switch combination is unique. If the design does not allow simultaneous switch presses, the resistor selection is greatly simplified.

Using a single comparator input to detect the switch presses requires that the input pin be changed to an output. This allows the capacitor to be pulled to ground. Afterward, the pin is changed back into the single comparator input to let the capacitor charge up. When the capacitor voltage reaches the comparator threshold voltage, the state of the comparator will change. The software will measure the time it takes the capacitor to charge to the threshold from the time the pin direction is changed.

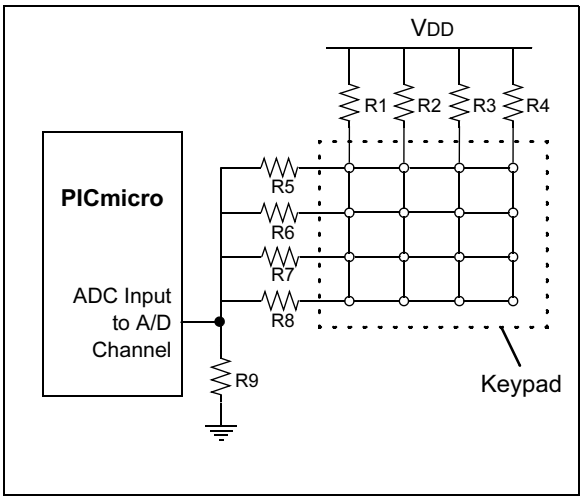
DIGITAL THRESHOLDS AND TIMING

The digital method is similar to the comparator method. In fact, the circuitry is the same. Instead of using a comparator threshold to detect the charge of the capacitor, the V_{IH} threshold is used. Since the V_{IH} threshold of a Schmitt trigger input is larger than the TTL input, it provides a larger input detection range. Therefore, it is best to use a Schmitt trigger input to detect the capacitor charge. The downside to using a digital input is the current consumption is higher. The higher current consumption is caused by placing intermediate analog voltages on a CMOS gate. V_{IH} charges between parts so calibration may be required.

Keypads to a Single Input

Keypads are commonly used to input numeric data into many applications. Therefore, PORTB on the PICmicro® microcontroller includes special features to simplify reading the keypad. While keypads have benefits, they require many pins in order to be functional. A typical 4x4 keypad requires eight I/O pins. Figure 3 illustrates a resistor network, which changes a 4x4 keypad into a switchable resistor matrix. The resulting resistance is read by an ADC or a capacitor charge timer, which determines the key that is pressed. This is practical only when one key is pressed at a time.

FIGURE 3: 4X4 KEYPAD RESISTOR NETWORK DIAGRAM



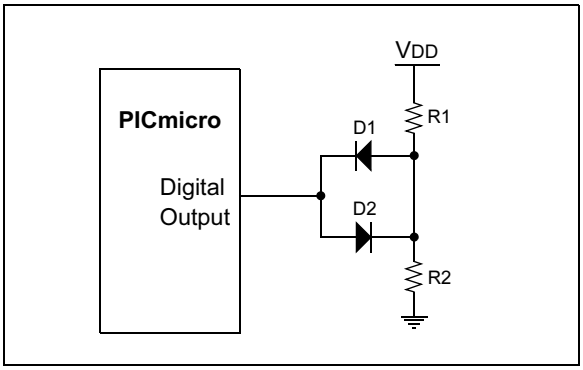
DRIVING MULTIPLE LEDS

Light emitting diode (LEDs) are one of the most popular devices connected to PICmicro microcontroller outputs. PICmicro microcontrollers are ideal drivers for LEDs because the output pins provide enough current to turn them on. Unfortunately, the number of output pins available is limited due to cost constraints. To solve this problem, we have a few suggestions. See Complementary LED Drive Technical Brief (TB029) for more information.

- 2 LEDs on a single I/O pin and
- 6 LEDs on 3 I/O pins
- 12 LEDs on 4 I/O pins

LED's are diodes that allow current to flow in one direction, which distinguishes them from filament light bulbs. With this in mind, Figure 4 shows how to drive 2 LEDs with 1 I/O pin.

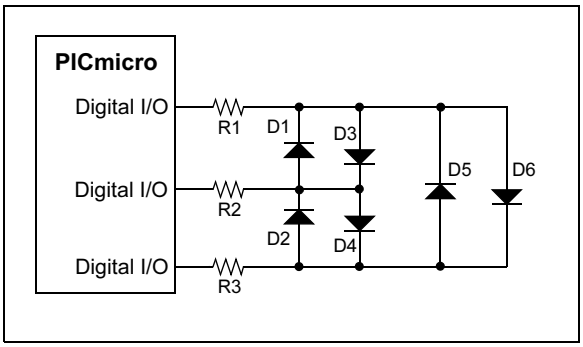
FIGURE 4: 2 LEDS ON 1 I/O PIN



© 2003 Microchip Technology Inc.

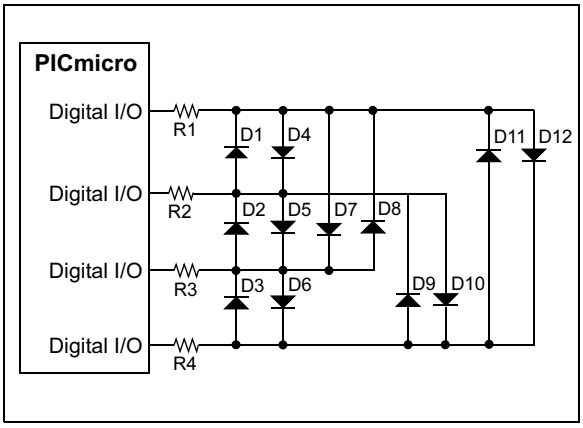
Driving two LEDs with one pin is simple. A bit more complex, driving 6 LEDs with 3 I/O pins is shown in Figure 5.

FIGURE 5: 6 LEDS ON 3 I/O PINS



If this concept is extended further, four I/O pins can be used to drive 12 LEDs as in Figure 6.

FIGURE 6: 12 LEDS ON 4 I/O PINS



Although this is a very interesting concept, there are potential problems with this approach. Additional software is required to drive this display. If the display is illuminating more than one LED at a time, then significant amounts of software time can be consumed multiplexing the LEDs to appear to be lit simultaneously. If the application is driving a dot matrix graphics display where each LED is one pixel, then the display will get dimmer as the LED count goes up. This is due to the amount of time spent switching one LED on at a time. The duty cycle and intensity is reduced. However, if the application's purpose is to light only 1 LED at a time, there is no reduction in intensity and this concept works well.

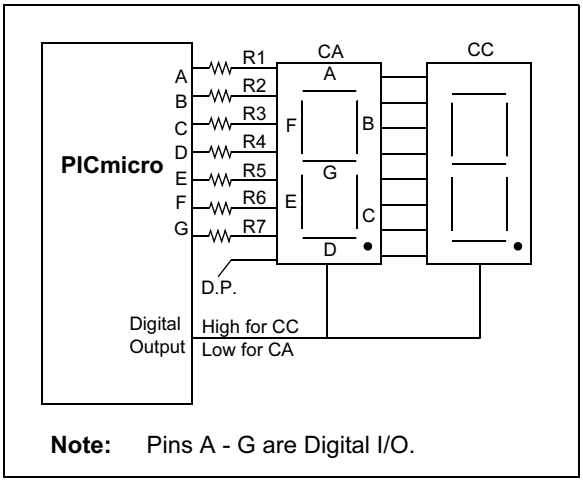
As mentioned earlier, driving this display requires some work. Each LED requires two outputs to be active, one high and one low. The rest of the pins are inputs so that no current flows through them. To light more than one LED at a time, the inputs and outputs must be re-configured often enough to appear that both LEDs are active at the same time. It is best to keep each LED on for the same amount of time and reserve time slots in the multiplexing for the LEDs that are not lit. If the multiplexing only cycles between active LEDs and ignores the inactive LEDs, the light intensity will decrease as additional LEDs are lit.

Driving Multiple Seven-segment Displays with 8 I/O Pins

Seven-segment displays are one of the most often used numeric (and sometimes alphanumeric) displays. Like the keypads, seven-segment displays require many output pins. They require output pins for each segment and may require output pins to control the common cathode (or anode) of each digit. In the case of a single digit display, pins are only required for the segments as the common cathode (or anode) can be tied to ground (or power). Which begs the question, how to drive multiple digits with only a small handful of pins.

If you only need to drive 2 digits, it is possible to use eight pins by mixing common cathode and common anode type displays. See Figure 7.

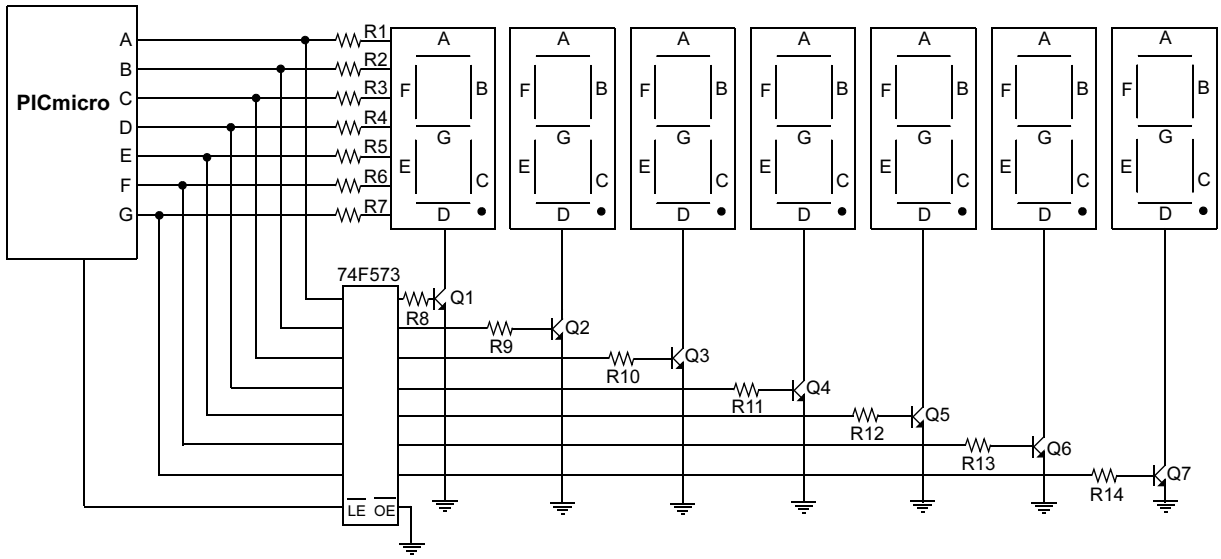
FIGURE 7: 2 DIGITS ON 8 I/O PINS



Note: Pins A - G are Digital I/O.

One method of driving two displays is to use two seven-segment display driver chips. These chips translate four bits of data into the correct segments pattern. Of course, if you need more than two digits, you will need additional help.

FIGURE 8: DIGIT EXPANSION USING AN OCTAL LATCH



Note: Pins A - G are Digital I/O.

Another technique is to use an octal latch, such as 74F573, to be the digit selection. See Figure 8.

To use the octal latch described in Figure 8, the latch must be loaded with the correct digit. The procedure is as follows:

1. Raise $\overline{LE}$ and set <A-G> to the desired digit pattern. <A> = 1 and <B-G> = 0 will enable G1 or Digit 1.
2. Lower $\overline{LE}$ and set <A-G> to display the correct numeral. <A-F> = 1 and <G> = 0 will display '0' on Digit 1.
3. Delay long enough for the reader to notice. With 3 ms per digit and 21 ms for all 7 digits, the result is a 47 Hz refresh rate.
4. Repeat.

SAVING OUTPUT PINS

Using Opto-isolators as Output Expansion

Earlier, a method was described to drive many LEDs with just a few I/O pins. This same technique can be used with opto-isolators to drive a large number of outputs with just a few I/O pins.

When D1 is activated, Q1 allows current to flow. This will reduce the voltage on C1 and activate the load. When D1 is deactivated, Q1 releases C1 and the voltage on C1 begin to rise. C1 will rise until M1 turns on and the load is deactivated. R1 and R2 slow the turn-on of M1 and provide the resistive component of a RC time constant. The time to turn off depends on the gate threshold of M1 and the RC time constant of (R1 + R2) x C. R2 should be chosen to limit the turn-on rate of M1. R1 is required to limit the turn off rate. C1 is added to further reduce the turn off rate and reduce the variation due to different gate capacitance. For example:

$$R1 = R2 = 1K$$
$$C1 = 1\mu F$$
$$V_{SUPPLY} = 12V$$
$$V_{GTH} = -5V$$

When M1 is on, V_{GATE} is 6V.

$$V_{C1} = 0V$$

To turn M1 off, V_{GATE} must reach 5V so:

$$V_{C1} \geq 2V$$

© 2003 Microchip Technology Inc.

Turn off time is the time it takes the capacitor to charge to 2V, solving:

$$V_T = V_{SUPPLY}\left(1 - C^{\frac{-T}{RC}}\right) \quad for\ T$$

$$T = -RC \cdot L_N\left(1 - \frac{V_T}{V_{SUPPLY}}\right)$$

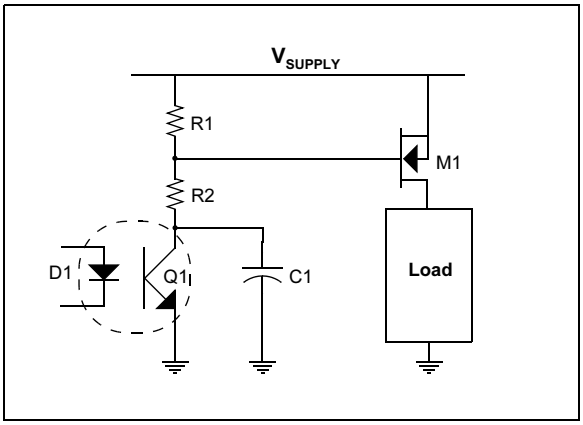
$$R = R1 + R2 = 2000$$

$$V_T = 2$$

$$T = 365\mu s$$

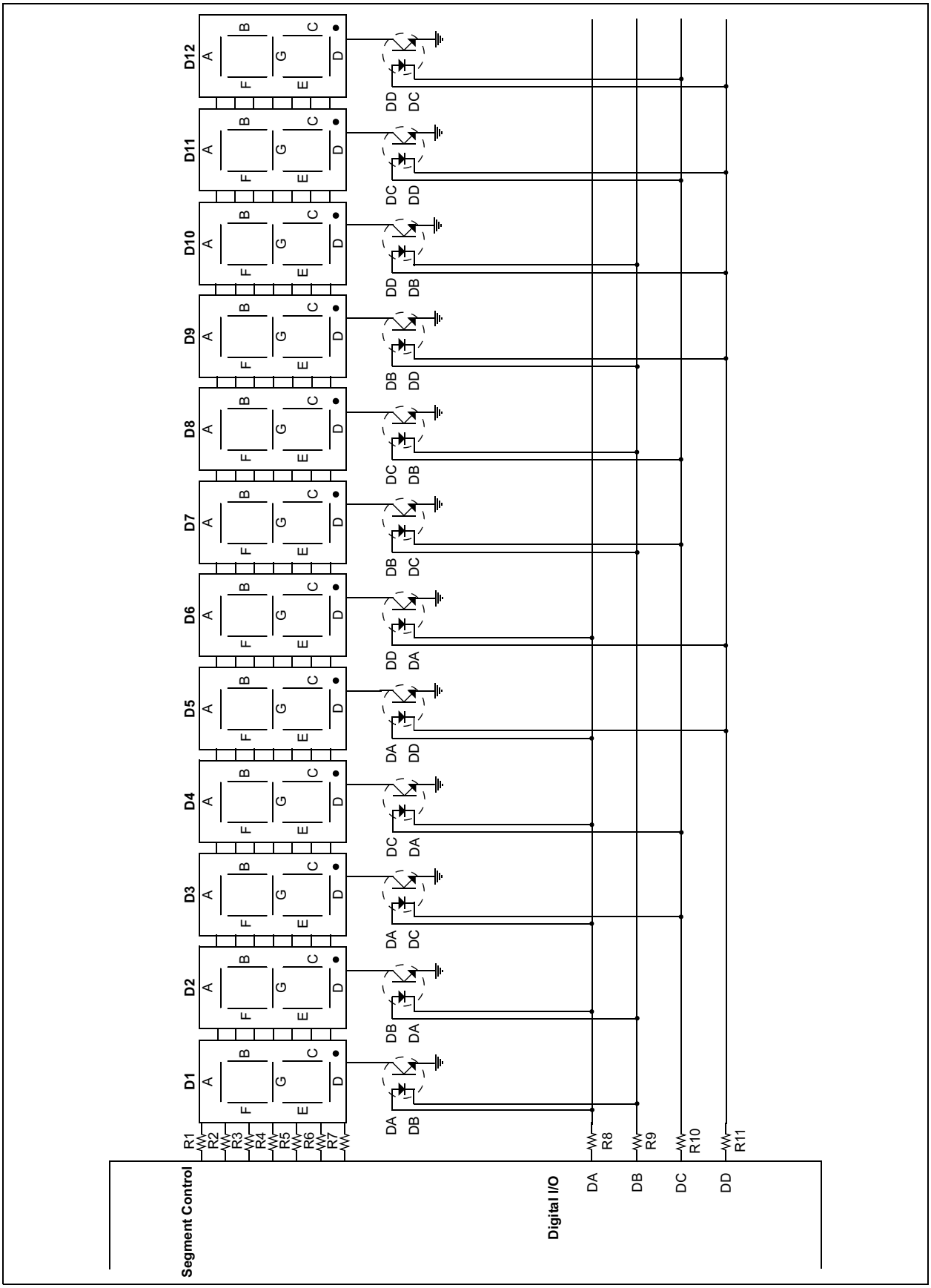
Refresh the output every 300 μs and the load will remain active. Ignore the output and the load will turn off.

FIGURE 9: OPTO-ISOLATOR CONTROLLED LOAD W/ AUTOMATIC TURN OFF



This method may not work for all applications. However, Figure 10 shows how seven-segment displays can use this technique to multiplex the digits.

FIGURE 10: 12 DIGIT MULTIPLEXING WITH OPTO-ISOLATORS



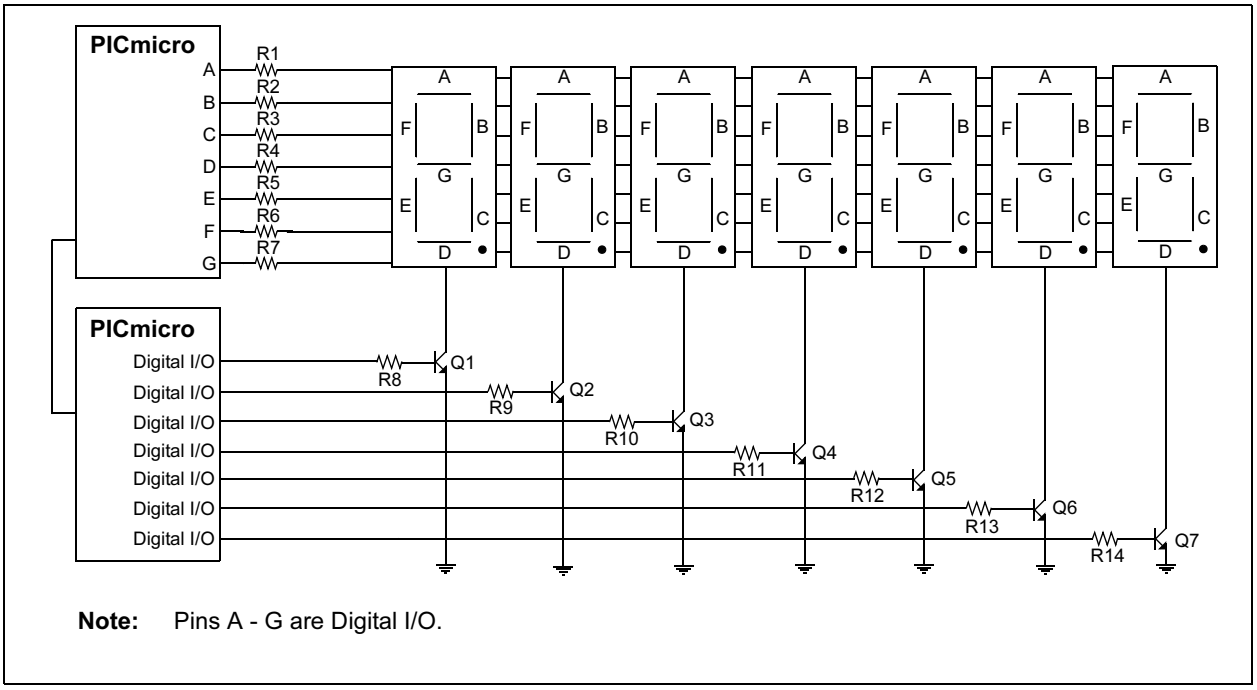
© 2003 Microchip Technology Inc.

Using PICmicro as Output Expansion

Many ideas for saving I/O pins require more cost. The previous example would add opto-isolators, which would increase cost. It is also possible to use discrete logic chips to add functionality and decrease pin usage. This works well, but often takes more than one. Consider using a second PICmicro microcontroller instead of additional logic chips. In many cases, small PICmicro microcontrollers are less expensive and take less board space than several logic ICs. The benefit is it's function. It can be specific to the application, which simplifies the code. A PICmicro microcontroller can easily be programmed to cycle through multiple seven-segment display digits at the command of one input pin. The multiplexer can be reset to the first digit by a longer pulse.

This application would take a few logic chips but it only requires one PICmicro microcontroller. By using two small PICmicro microcontrollers, it may be easier to fit the design into a small irregular space, where a single high-pin count device would not fit.

FIGURE 11: PICMICRO AS I/O EXPANDER



Note: Pins A - G are Digital I/O.

MAXIMIZING PIN USAGE

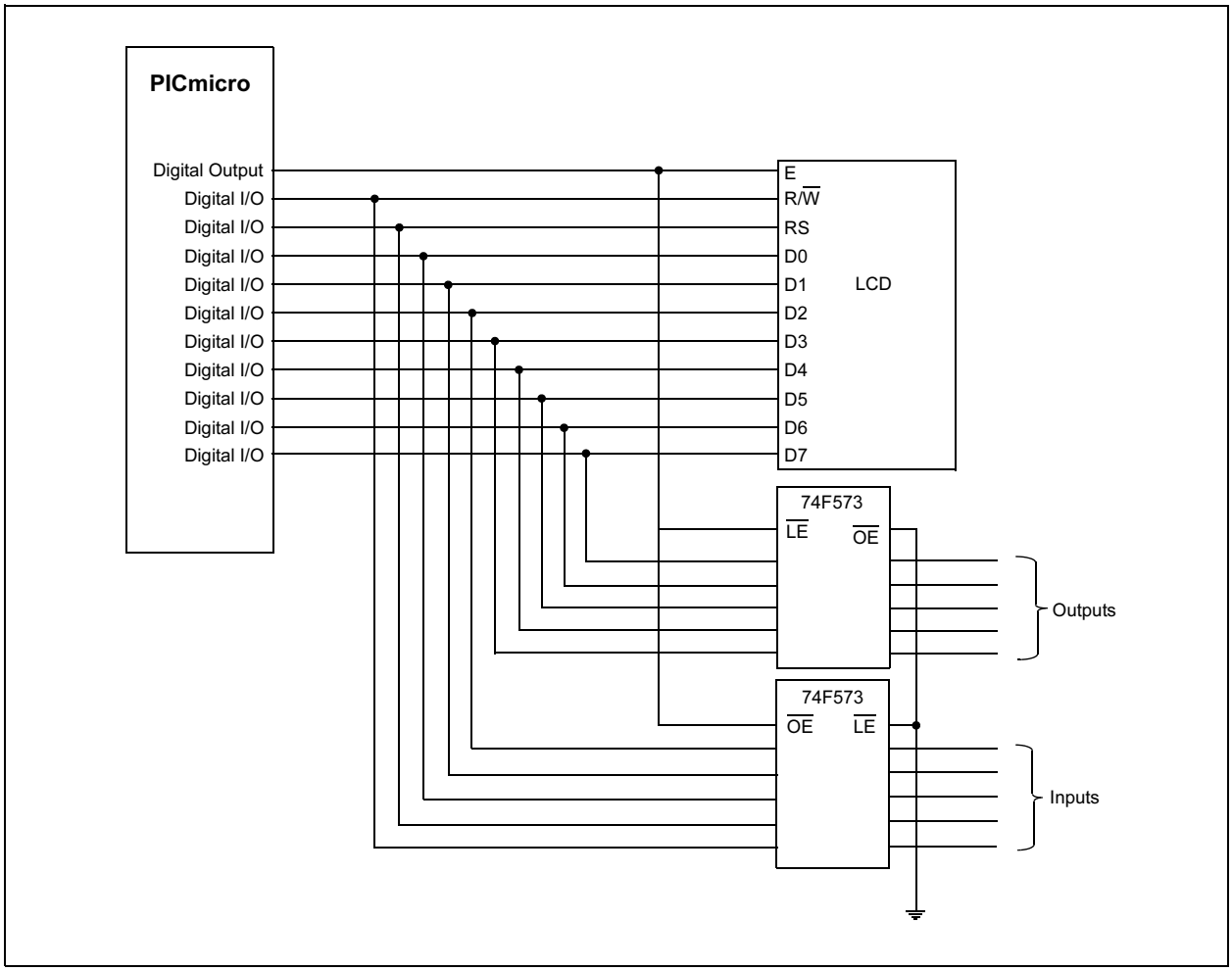
Sharing I/O Pins with LCD's

HD44780A type LCD's may be the most popular alpha-numeric display used with embedded systems. They are simple to interface and are quite flexible in their output. The only down side is they use 6 to 11 I/O pins. It would be more useful if the pins could accomplish additional features. With proper technique, it is possible to reuse the LCD control pins. The LCD latches data while the E pin is high. As long as the E pin is low, the remaining pins can be used for any function. Although, there are a few issues:

1. If the application is an output, it must accept the pin transitions while the pin is driving the LCD;
2. If the application is an input, it must not drive the pin harder than the LCD.

Of course, these two issues can be reduced if the port is gated with a bus transceiver and the E clock is used to enable or disable the link between the LCD Port pins and the application.

FIGURE 12: SHARING I/O PINS WITH LCD CONTROLLER



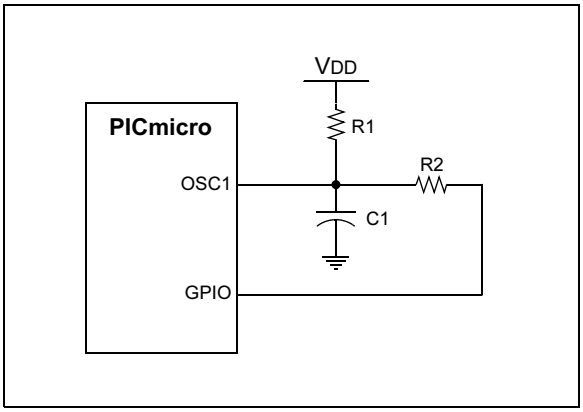
© 2003 Microchip Technology Inc.

POWER SAVING TRICKS

Variable Frequency RC Oscillator

The external RC oscillator is inexpensive and easy to use. Unfortunately, it only has one setting. By using a free I/O pin, a second resistor or capacitor can be added to the circuit to shift the frequency. By doing this, you have a multi-speed RC oscillator creating low speed for low current and high speed for quick math.

FIGURE 13: VARIABLE SPEED RC OSCILLATOR



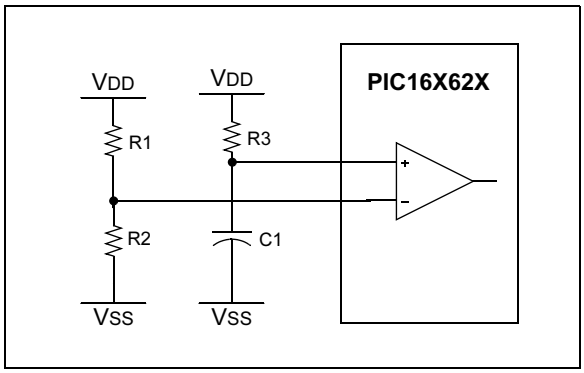
RC Watchdog Wake-up

The watchdog timer is very useful for protecting your code or waking the microcontroller up out of SLEEP mode. However, for some applications it consumes too much power. If your microcontroller has a comparator, use a resistor and capacitor on the comparator to provide the wake-up. Simply wire the R and C to the comparator input, program the threshold voltage, and enable the interrupt. Then, zero the capacitor and go into SLEEP mode. The capacitor will charge, reach the threshold, cause an interrupt, and wake-up your program. See procedure steps below. The RC network can be designed to use very little current.

WAKE-UP PROCEDURE

1. Set comparator input to a digital output.
2. Write a zero to clear the capacitor.
3. Set the comparator input back to a comparator input.
4. Read the comparator state flag to clear it.
5. Enable the comparator interrupt.
6. Set to SLEEP.

FIGURE 14: LOW CURRENT WAKE-UP



CONCLUSION

This document is filled with ideas that have been successfully used to reduce cost or simplify designs. This is not a comprehensive list of cost saving ideas and these ideas may not work for all situations.

Hopefully, these ideas have sparked your imagination to the possibilities of alternate ways to use a PICmicro microcontroller.

REFERENCE DOCUMENTS

Complementary LED Drive Technical Brief, TB029; Microchip Technology Inc.

NOTES:

© 2003 Microchip Technology Inc.

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

Trademarks

The Microchip name and logo, the Microchip logo, KEELOQ, MPLAB, PIC, PICmicro, PICSTART, PRO MATE and PowerSmart are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, microID, MXDEV, MXLAB, PICMASTER, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

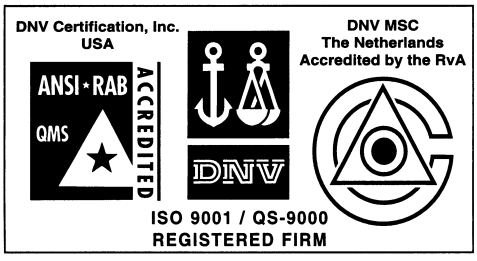
Accuron, Application Maestro, dsPIC, dsPICDEM, dsPICDEM.net, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, PICC, PICkit, PICDEM, PICDEM.net, PowerCal, PowerInfo, PowerMate, PowerTool, rfLAB, rfPIC, Select Mode, SmartSensor, SmartShunt, SmartTel and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

Serialized Quick Turn Programming (SQTP) is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2003, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

Printed on recycled paper.



Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001 certified.

WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200 Fax: 480-792-7277
Technical Support: 480-792-7627
Web Address: http://www.microchip.com

Atlanta
3780 Mansell Road, Suite 130
Alpharetta, GA 30022
Tel: 770-640-0034 Fax: 770-640-0307

Boston
2 Lan Drive, Suite 120
Westford, MA 01886
Tel: 978-692-3848 Fax: 978-692-3821

Chicago
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0071 Fax: 630-285-0075

Dallas
4570 Westgrove Drive, Suite 160
Addison, TX 75001
Tel: 972-818-7423 Fax: 972-818-2924

Detroit
Tri-Atria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

Kokomo
2767 S. Albright Road
Kokomo, Indiana 46902
Tel: 765-864-8360 Fax: 765-864-8387

Los Angeles
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

Phoenix
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-4338

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

Australia
Microchip Technology Australia Pty Ltd
Marketing Support Division
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
Rm. 2401-2402, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-86766200 Fax: 86-28-86766599

China - Fuzhou
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

China - Hong Kong SAR
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

China - Shanghai
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

China - Shenzhen
Microchip Technology Consulting (Shanghai) Co., Ltd., Shenzhen Liaison Office
Rm. 1812, 18/F, Building A, United Plaza
No. 5022 Binhe Road, Futian District
Shenzhen 518033, China
Tel: 86-755-82901380 Fax: 86-755-82966626

China - Qingdao
Rm. B505A, Fullhope Plaza,
No. 12 Hong Kong Central Rd.
Qingdao 266071, China
Tel: 86-532-5027355 Fax: 86-532-5027205

India
Microchip Technology Inc.
India Liaison Office
Marketing Support Division
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-6334-8870 Fax: 65-6334-8850

Taiwan
Microchip Technology (Barbados) Inc., Taiwan Branch
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Austria
Microchip Technology Austria GmbH
Durisolstrasse 2
A-4600 Wels
Austria
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

Denmark
Microchip Technology Nordic ApS
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Microchip Technology GmbH
Steinheilstrasse 10
D-85737 Ismaning, Germany
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy
Microchip Technology SRL
Via Quasimodo, 12
20025 Legnano (MI)
Milan, Italy
Tel: 39-0331-742611 Fax: 39-0331-466781

United Kingdom
Microchip Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

03/25/03

© 2003 Microchip Technology Inc.