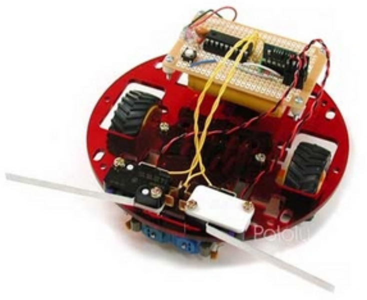
PIC-Based, Obstacle-Avoiding Robot



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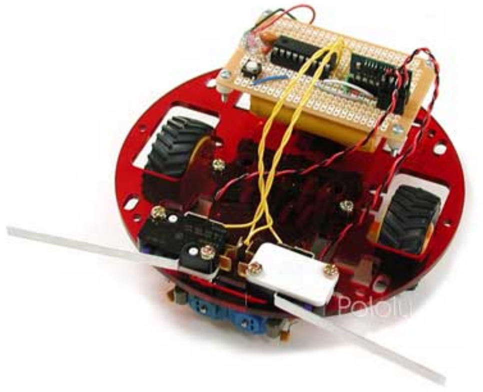
1. Introduction



One of the biggest challenges in building your own robot is controlling its motors. You can find new or surplus motors and gearboxes in many places, and low-cost microcontrollers and books on how to use them abound. However, microcontrollers cannot directly drive DC motors, leaving robotics beginners with the possibly overwhelming challenge of building their own motor controller. This task is even more complicated if the motors require bidirectional operation and speed control.

This project demonstrates how easy it is to make a simple robot controller using the **Pololu micro dual serial motor controller** **[http://www.pololu.com/catalog/product/410]** with a **Microchip** **[http://www.microchip.com/]** PIC16F628 microcontroller. We then use the circuit with the **Pololu robot chassis** **[http://www.pololu.com/catalog/product/250]** to create a small, obstacle-avoiding robot that can serve as a starting point for more advanced projects. The low-voltage operation of the motor controller allows a small, 3.6 V cordless telephone battery pack to power the entire robot. Since the motor controller only requires two of the PIC's 13 I/O lines, there is plenty of opportunity for expansion.

2. Materials and Tools

Here are the essential parts you will need if you want to build a similar robot. These items are available either from Pololu or from most electronic component distributors.

- **Pololu micro dual serial motor controller [http://www.pololu.com/catalog/product/410]**
- **Pololu robot chassis plate [http://www.pololu.com/catalog/product/250]**
- Parts to build the robot chassis, which come with our chassis combination kits:
    - **Tamiya twin-motor gearbox [http://www.pololu.com/catalog/product/61]** (Tamiya #70097)
    - **Tamiya ball caster [http://www.pololu.com/catalog/product/66]** (Tamiya #70144)
    - **Tamiya truck tires [http://www.pololu.com/catalog/product/65]** (Tamiya #70101)
- **PIC16F627** or **PIC16F628** microcontroller in a DIP (dual in-line package) from **Microchip [http://www.microchip.com/]**. The 16F62X microcontrollers are the only 18-pin PICs that have a built in UART (universal asynchronous receiver and transmitter), which makes transmitting data serially (to the motor controller) very simple. The code presented in this project should be portable to any other PIC with a hardware UART; with the other PICs, you would have to write your own serial routines (which isn't that bad since you only need to transmit, and the motor controller should handle any baud rate you come up with).
- **Clock source** for the PIC. We used a 4 MHz ceramic resonator with built-in capacitors; any crystal, resonator, or oscillator in the 1-20 MHz range should be fine.
- **18-pin DIP socket** for the PIC. You may also want a socket for your motor controller; a crude way of obtaining a 9-pin SIP (single in-line package) socket is to cut an 18-pin DIP socket in half.
- Two **long-lever, snap-action switches** for use as bumpers switches.
- **3.6 V, 650 mAh cordless telephone battery pack** (or three AA size NiCd or NiMH batteries in a battery holder). Cordless phone batteries are available in many consmer electronics stores (e.g. Radio Shack, Best Buy) and discount stores (e.g. Wal-Mart) for around $10, making them a great power source for small robots.
- General-purpose **prototyping PC board [http://www.pololu.com/catalog/category/32]** (or proto board) with space for two 18-pin DIP sockets, the ceramic resonator, and whatever other electronics you might want to fit. Such boards are available from most electronics component stores, including Radio Shack (e.g. part number 276-150A). To avoid soldering, this project could also be done using a small **wireless breadboard [http://www.pololu.com/catalog/product/350]**, such as the one used in **project 2 [http://www.pololu.com/docs/0J3]**.
- **Hook-up wire [http://www.pololu.com/catalog/product/354]** and **solder** for making all of your connections.
- **Double-sided foam tape** provides a quick way of temporarily mounting items such as the battery pack. Alternatively, you could use standard mounting hardware or cable ties for fixing your components to the chassis.

You will probably also want to use the following:

- Pushbutton switch and 10k resistor for a reset circuit
- Two 0.1 uF capacitors to solder across the motor terminals
- Power switch

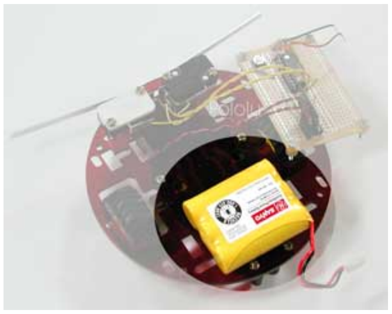
You will also need these basic tools:

- **Soldering iron [http://www.pololu.com/catalog/category/5]**

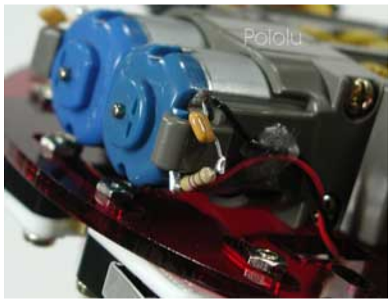
- **Diagonal cutters** **[http://www.pololu.com/catalog/product/159]**
- **Wire strippers** **[http://www.pololu.com/catalog/product/161]**
- Scissors
- **Phillips screwdriver** **[http://www.pololu.com/catalog/product/158]** (for building the gearbox and ball caster)
- Hot glue gun (optional)

3. Hardware Construction

Begin by assembling the robot chassis. You should mount the battery pack on the rear of the robot, above the ball caster, to balance the weight of the motors. Double-sided foam tape is a convenient method of attaching the battery pack; it can also be secured with cable-ties by using the rectangular holes on both sides of the ball caster. If you are using a battery holder, you can easily drill mounting holes through the holder or the chassis if existing holes do not line up.

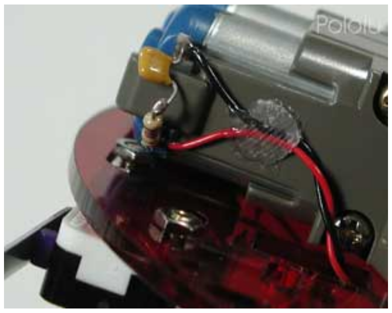


When soldering to the motor leads, be careful not to damage them. Soldering a small capacitor across the motor leads can improve the performance of the motor controller and lower interference with other electronics on your robot. We used a 0.1 uF ceramic capactitor.



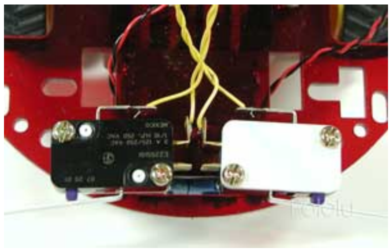
The picture to the right shows a resistor in series with the capacitor. In general, such a resistor limits the current wasted by the PWM (pulse width modulation) in charging and discharging the capacitor. However, the relatively low, 600 Hz PWM frequency of the motor controller makes this resistor unnecessary; we saw no added benefit when we added the resistor.

Because the motor leads are fragile, it is important to provide strain relief for the wires you connect to the motor. For our example, we hot-glued the leads to the side of the gearbox, as shown in the picture. Securing the wires this way will allow you to manipulate the other end of the wires without worrying about breaking off the motor leads. Note that the glued wires prevent removal of the motors from the gearbox. Hot glue has the advantage of not being entirely permanent; if necessary, it's not too difficult to free the wires.

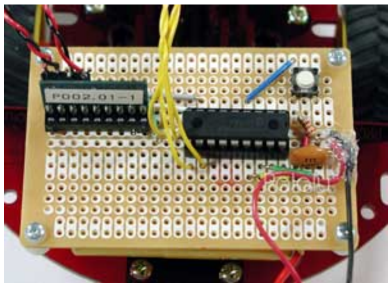


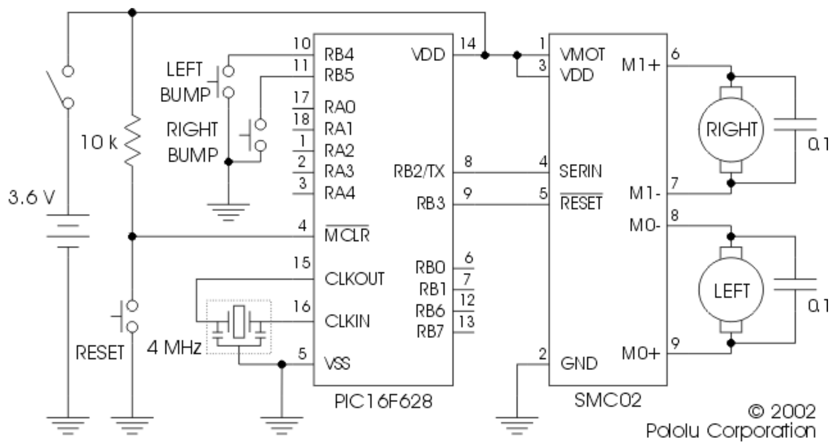
We have kept the motor capacitor exposed for the purposes of these pictures, but it's a good idea to protect them as much as possible, especially since they are low to the ground and on the front end of the robot.

To keep this project as simple as possible, we limit our sensors to two snap-action swtiches for front collision detection. Of course, you can add more sophisticated sensors for more interesting behavior.



As you can see in the picture to the right, there isn't much to the electronics. We soldered the circuit on a small perforated board, but you can also use a solderless breadboard. The small pushbutton switch on the top right and the resistor below it make up an optional reset circuit. The only other components are the PIC, the resonator (lower right), and the motor controller. No additional resistors are required for the bump switches because we use the PIC's internal pull-up resistors on port B.





Schematic diagram for Pololu sample project 1: PIC-based, obstacle-avoiding robot

The main reason for using the PIC16F628 is that it has a hardware UART; to make use of it, we must connect the TX pin, pin RB2, to the motor controller's serial input. Connecting the motor controller reset pin is optional, but using it prevents any baud rate detection problems during power-up. If you don't have any extra I/O lines, you can connect the reset input to the PIC reset circuit.

Note that the bumper switches must be connected to port B pins in order to make use of the PIC's internal pull-up resistors. Nine of the PIC I/O lines are unused and available for expansion. As you add additional electronics, you may need to add 0.1 uF bypass capacitors from power to ground to keep the power supply clean. As you can see in the picture to the right, there isn't much to the electronics. We soldered the circuit on a small perforated board, but you can also use a solderless breadboard. The small pushbutton switch on the top right and the resistor below it make up an optional reset circuit. The only other components are the PIC, the resonator (lower right), and the motor controller. No additional resistors are required for the bump switches because we use the PIC's internal pull-up resistors on port B.

4. Software for the PIC

Using the motor controller is very simple, even if you program your PIC in assembly. This sample program makes our little robot drive forward until it hits an obstacle; once it does, it backs up, turns away from the side where the collision occured, and resumes moving forward. All of the code below uses the standard assembly language supported by Microchip's MPLAB development software. Even if you are using a different assembler or compiler, this example should give you a good start.

First, we name the registers and bits that we will use throughout the rest of the program:

```
;****** Equates ****************************************************************

Bank0RAM    equu    020h    ;start of bank 0 RAM area

SMC_PORT    equ     PORTB    ;motor controller on port b
BMP_PORT    equ     PORTB    ;bumper switches on port b

;bit equates
SOUT        equ     2    ;serial output to motor controller
SRST        equ     3    ;to reset pin on motor controller
LBMP        equ     4    ;left bumper switch
RBMP        equ     5    ;right bumper switch

;****** Variables **************************************************************

    cblock    Bank0RAM
    ARG1L
    ARG1H
    BYTE3    ;for storing bytes 3 and 4 in the serial protocol
    BYTE4
    endc
```

It's also convenient to have a subroutine for making precise pauses. This routine takes the 16-bit value in ARG1H and ARG1L and delays for approximately that many milliseconds. Of course, the length of the delay is dependent on the clock speed, which is 4 MHz in our example.

```
milliDelay
    movlw    .250        ;outer loop
    addlw    0xFF        ;inner loop
    btfss    STATUS,Z
    goto    $-2        ;goto inner loop

    movlw    1        ;16-bit decrement
    subwf    ARG1L,f
    btfss    STATUS,C
    decf    ARG1H,f

    movf    ARG1H,f        ;16-bit test if zero
    btfsc    STATUS,Z
    movf    ARG1L,f
    btfsc    STATUS,Z
    return
    goto    milliDelay
```

We are now ready to approach the main program, which begins by configuring the UART and resetting the motor controller. The 2 millisecond pause at the end gives the motor controller some time between resetting and receiving serial input.

```
    org    0x05
startMain
    ;set up I/O ports and serial port for 19,200 baud UART
    bsf    STATUS,RP0
    movlw    b'11110111'    ;smc reset is the only normal
    movwf    TRISB        ; output--all others inputs or serial out
    bcf    OPTION_REG,NOT_RBPU    ;enable PORTB pull-up resistors
    movlw    .12        ;set baud rate to 19,200 (assuming BRGH=1)
    movwf    SPBRG        ;(address 99h)
    movlw    b'00100100'    ;bit 6 clear - 8-bit transmission
               ;bit 5 set - enable transmit
               ;bit 4 clear - UART asynchronous mode
               ;bit 2 set - high baud rate mode
               ;bits 7, 3, 1, 0 - don't care
    movwf    TXSTA        ;address 98h
    bcf    STATUS,RP0    ;select bank 0
    movlw    b'10010000'    ;bit 7 set - enable serial port
               ;bit 6 clear - 8-bit reception
               ;bit 4 set - continuous receive
               ;bits 5, 3:0 - don't care
    movwf    RCSTA        ;address 18h
    ;reset motor controller
    bcf    SMC_PORT,SRST
    nop
    nop
    bsf    SMC_PORT,SRST
    movlw    0x00
    movwf    ARG1H
    movlw    0x02
    movwf    ARG1L
    call    milliDelay
```

The program is now ready to run its main loop, in which it checks the bumper switches and takes the appropriate action. Two supporting subroutines, `updateMotor` and `pause`, are shown later; `updateMotor` sends a 4-byte command to the motor controller based on `BYTE3` and `BYTE4`, and `pause` stops both motors for 50 ms. `pause` is used to keep the motors from having to instantly switch from forward to reverse, which causes a current surge that can exceed the motor controller's maximum current specification of 1 A.

```
mainLoop
    btfss    BMP_PORT,LBMP
    goto    left_bump
    btfss    BMP_PORT,RBMP
    goto    right_bump
    ;no bumps, so just go straight
    movlw    0x00        ;right motor, forward
    movwf    BYTE3
    movlw    0x7F        ;full speed
    movwf    BYTE4
    call    updateMotor
    movlw    0x02        ;right motor, forward
    movwf    BYTE3
    movlw    0x7F        ;full speed
    movwf    BYTE4
    call    updateMotor
    goto    mainLoop

left_bump
    call    pause
    movlw    0x03        ;right motor, backward
    movwf    BYTE3
    movlw    0x7F        ;full speed
    movwf    BYTE4
    call    updateMotor
    movlw    0x01        ;left motor, backward
    movwf    BYTE3
    movlw    0x3F        ;half speed
    movwf    BYTE4
    call    updateMotor
    movlw    HIGH .1500    ;pause 1.5 seconds (1500 ms)
    movwf    ARG1H
    movlw    LOW .1500
    movwf    ARG1L
    call    milliDelay
    call    pause
    goto    mainLoop

right_bump
    call    pause
    movlw    0x03        ;right motor, backward
    movwf    BYTE3
    movlw    0x3F        ;half speed
    movwf    BYTE4
    call    updateMotor
    movlw    0x01        ;left motor, backward
    movwf    BYTE3
    movlw    0x7F        ;full speed
    movwf    BYTE4
    call    updateMotor
    movlw    HIGH .1500    ;pause 1.5 seconds (1500 ms)
    movwf    ARG1H
    movlw    LOW .1500
    movwf    ARG1L
    call    milliDelay
    call    pause
    goto    mainLoop
```

Finally, here are the subroutines called from the main loop. The `updateMotor` subroutine sends the motor controller the 4-byte control sequence of 0x80 and 0x00 followed by the motor number and direction, specified in `BYTE3`, and the speed, specified in `BYTE4`. To keep this example program simple, this subroutine does not exit until all four bytes have been copied to the transmit buffer. The program could be made more efficient by using interrupts, allowing the PIC to perform other tasks while the UART is busy transmitting.

```
updateMotor
    btfss    PIR1,TXIF
    goto    updateMotor
    movlw    0x80
    movwf    TXREG
    nop
updateMotor2
    btfss    PIR1,TXIF
    goto    updateMotor2
    movlw    0x00
    movwf    TXREG
    nop
updateMotor3
    btfss    PIR1,TXIF
    goto    updateMotor3
    movf    BYTE3,W
    movwf    TXREG
    nop
updateMotor4
    btfss    PIR1,TXIF
    goto    updateMotor4
    movf    BYTE4,W
    movwf    TXREG
    return

pause
    movlw    0x02        ;right motor off
    movwf    BYTE3
    movlw    0x00
    movwf    BYTE4
    call    updateMotor
    movlw    0x00        ;left motor off
    movwf    BYTE3
    movlw    0x00
    movwf    BYTE4
    call    updateMotor
    movlw    HIGH .50    ;pause 0.05 second (50 ms)
    movwf    ARG1H
    movlw    LOW .50
    movwf    ARG1L
    call    milliDelay
    return
```

Note: Make sure the watchdog timer is disabled in the configuration bits. The brown-out detection feature must also be turned off for the PIC to operate off of the 3.6 V power source.

5. Results and Conclusion

Our robot performed as expected, and it was fairly entertaining to watch it bounce around the room. The bumper switches are far from perfect, with a blind area in the center of the robot that can get the robot stuck behind table legs and other obstacles too narrow to trigger either of the switches. This problem could be avoided by adding a third, center switch, or by making the robot turn randomly every once in a while.

One serious problem we did initially encounter was with changing the direction of the motors from full speed in one direction to full speed in the other direction. In highly cluttered areas, in which the robot frequently hit obstacles and changed directions, the motor controller would sometimes heat up to the point where the thermal cutoff kicked in, causing the robot to stop for approximately one second. After adding the 50 ms pauses between switching directions, we did not have any problems with the motor controller overheating.

This project shows that building a small robot is very simple when using the Pololu motor controller. In only a few hours, we built a functioning robot that can serve as a starting point for more complicated robots. If you are ready to tackle a new project, you might try adding on our **IR beacon** **[http://www.pololu.com/catalog/product/701]** to allow the robot to run away from another robot.