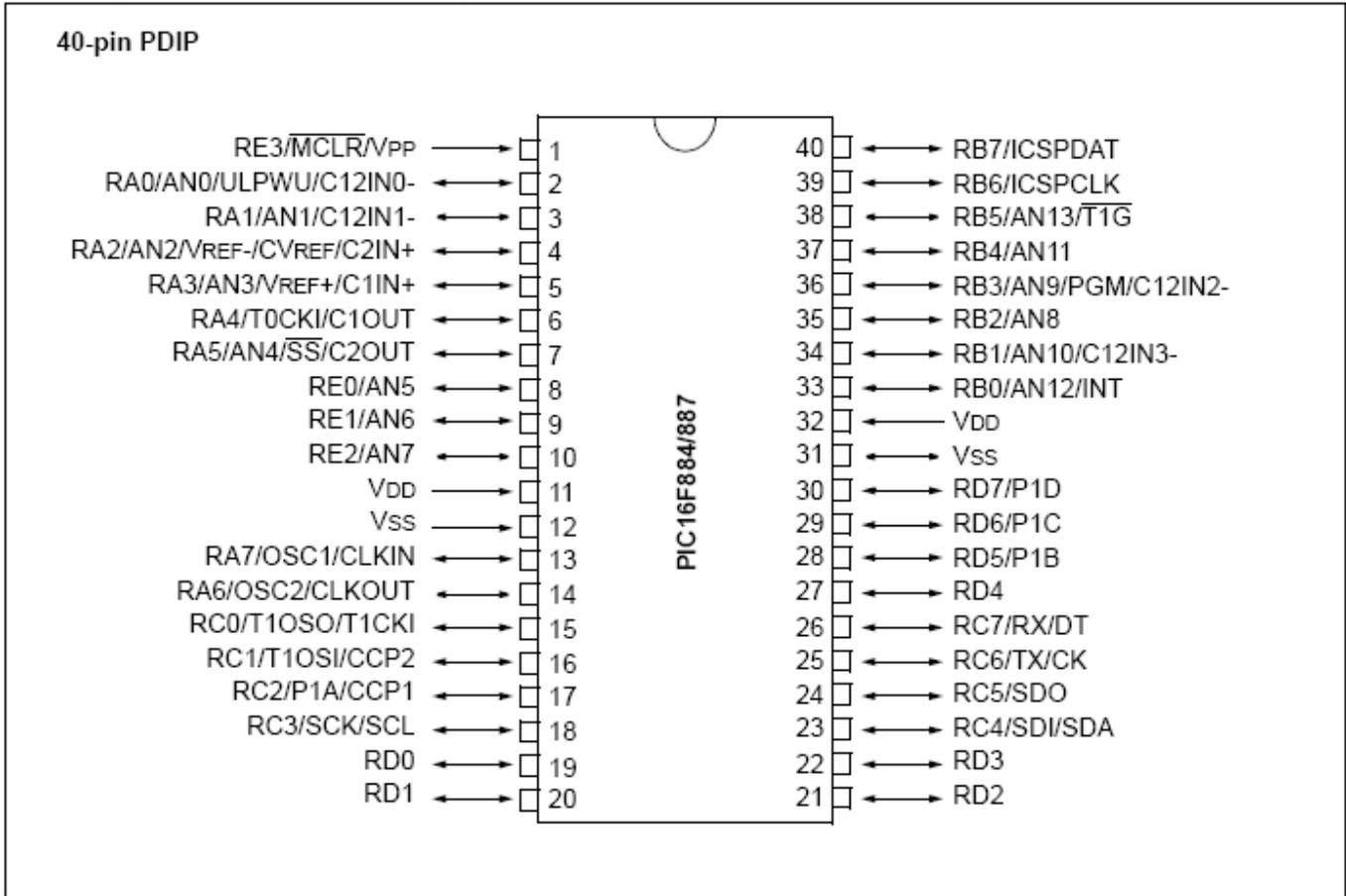# Lab Handout

For

11080 BDC
Intelligently Controlling Brushed DC Motor Control

Microchip Technology's
Masters Conference 2007

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PIC16F887 Pin Diagram

40-pin PDIP

RE3/$\overline{MCLR}$/VPP →	1	40 ← RB7/ICSPDAT
RA0/AN0/ULPWU/C12IN0- ↔	2	39 ↔ RB6/ICSPCLK
RA1/AN1/C12IN1- ↔	3	38 ↔ RB5/AN13/$\overline{T1G}$
RA2/AN2/VREF-/CVREF/C2IN+ ↔	4	37 ↔ RB4/AN11
RA3/AN3/VREF+/C1IN+ ↔	5	36 ↔ RB3/AN9/PGM/C12IN2-
RA4/T0CKI/C1OUT ↔	6	35 ↔ RB2/AN8
RA5/AN4/$\overline{SS}$/C2OUT ↔	7	34 ↔ RB1/AN10/C12IN3-
RE0/AN5 ↔	8	33 ↔ RB0/AN12/INT
RE1/AN6 ↔	9	32 ← VDD
RE2/AN7 ↔	10	31 ← VSS
VDD →	11	30 ↔ RD7/P1D
VSS →	12	29 ↔ RD6/P1C
RA7/OSC1/CLKIN ↔	13	28 ↔ RD5/P1B
RA6/OSC2/CLKOUT ↔	14	27 ↔ RD4
RC0/T1OSO/T1CKI ↔	15	26 ↔ RC7/RX/DT
RC1/T1OSI/CCP2 ↔	16	25 ↔ RC6/TX/CK
RC2/P1A/CCP1 ↔	17	24 ↔ RC5/SDO
RC3/SCK/SCL ↔	18	23 ↔ RC4/SDI/SDA
RD0 ↔	19	22 ↔ RD3
RD1 ↔	20	21 ↔ RD2

PIC16F884/887

Lab 1

Brushed DC Motor Control Using the CCP.

This lab uses the PWM mode of the Capture Compare PWM (CCP) module in the PIC16F887 Micro Controller, to create a hardware PWM to control the speed of the brushed DC motor on the Mechatronics Demo Board. First, we will run the PWM at a frequency of 2kHz, adjust the motor speed using POT1 and make observations. Next, we will run the PWM at a frequency of 80kHz, adjust the motor speed using POT1 and observe how the motor characteristics change based on frequency.

Procedure:

1. Wire the Mechatronics board as shown in figure 1 and the Pic16F887 pin diagram on page 2. Use the supplied jumpers for the following connections:

- RC1 (J13) to P1 (J1)
- RA2 (J13) to POT1 (J4)
- Make sure there are no shunts (two pin jumpers) on J2 and J3.
- Attach the brushed DC motor leads to DRIVE 1 (P9) and GND (P20).
- Connect the right and center pins of JP8 using a shunt. This will put 5 volts across the brushed DC motor.

2. Make sure the ICD 2 programmer is connected to the USB cable, and Mechatronics Demo Board via the ICD connector, at the lower left hand corner of the demo board. Next, connect the other 9volt power supply to the Mechatronics Demo Board and press the **CLR Fault button** at the bottom of the Demo Board next to the yellow light. The light will turn off after the button is pressed. The brushed DC motor will come on.

3. Also, connect the serial cable to the 9 pin serial connector at the upper left hand corner of the Mechatronics Demo Board. Then click the **Start** tab at the lower left hand corner of the windows screen. Under **Programs → Accessories → Communications** click on the **Hyper Terminal**. The New Connection window will appear. Type **Lab1** in the description box and click **OK**. In the next window select **COM1** then click **OK**. In the **Port Setup** window select; 9600 baud rate, 8 data bits, Polarity None, Stop bits 1, and Flow control Hardware then click **Apply** then **OK**.

4. Double click the **Masters folder** icon on the PC's desktop. Go into the **11080_BDC folder**, double click the **Labs folder**, and select **Lab1 folder**. Now, open **Lab1.mcw** workspace file and MPLAB IDE program will automatically open at the Lab1 workspace.

5. The Output window should indicate that ICD 2 connection has been established automatically and is ready. Also the **Lab1.asm** program file will automatically appear in the MPLAB IDE Editor window.

6. Now, click the **Project** tab on the menu above. Then click **Build All**. The Output window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application.

7. Next, click the **Programmer** tab on the menu above. Then click **Program**. Next, click **Release from Reset**

under the same menu tab. The brushed DC motor will turn off.

8. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

9. Now, the program is running and you can turn POT1 to adjust the speed of the brushed DC motor. Now, the speed of the brushed DC motor will appear inside the Hyper Terminal window.

Note:

Notice that the speed of the brushed DC motor max's out when POT1 is fully open. This is due to the PWM frequency is at 2 kHz. You can also notice that the motor is giving off a slight whining sound, also due to the low frequency.

10. Next, plug the ICD 2 cable back into the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board. Then click the **Programmer** tab on the menu above. Click **Hold in Reset**, the brushed DC motor will turn on.

11. Inside the **Lab1.asm** program located in the MPLAB IDE Editor window look for the **Change Period** box. To the far left of this line, change the value from 0x3E to **0x08**. This will change the PWM period to 1, thus changing the PWM frequency to 14 kHz.

12. Now, click the **Project** tab on the menu above. Then click **Build All**. The Output window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application.

13. Next, click the **Programmer** tab on the menu bar above then click **Program**. The **Output** window will say "Programming succeeded, MPLAB ICD 2 Ready".

14. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

15. Now, the program is running and you can turn POT1 to adjust the speed of the brushed DC motor. The speed of the brushed DC motor will appear inside the Hyper Terminal window.

Note:

Notice that the speed of the brushed DC motor max's out almost immediately after opening POT1. This is due to the PWM frequency is at 14 kHz. You can also notice that the motor is not giving off a whining sound, also due to the high frequency.

16. Finally, unplug the 9volt power supply from the Mechatronics Demo Board. Then exit from MPLAB IDE. This is the end of Lab1.

Figure 1. Jumper Diagram
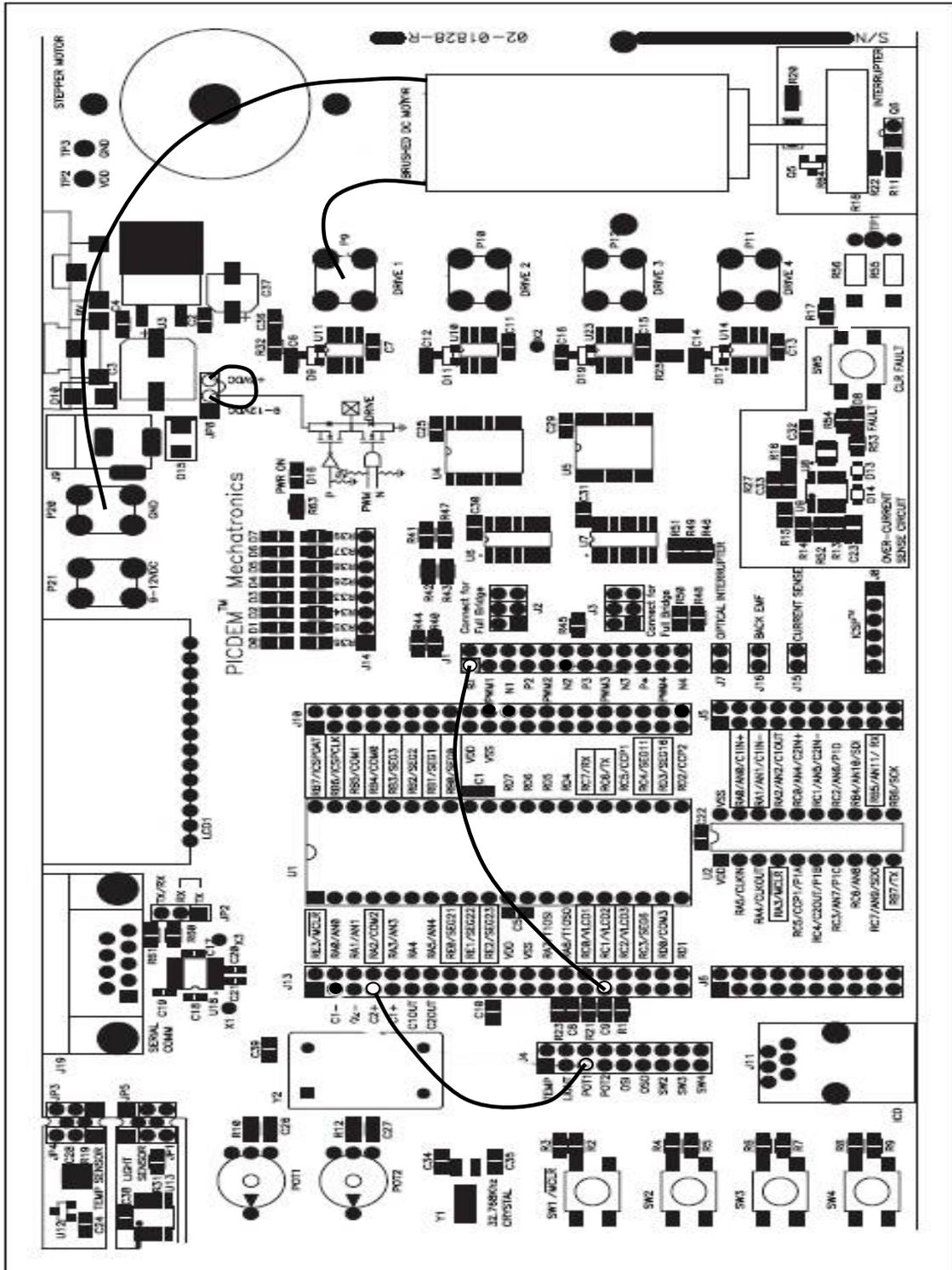
Lab 2

Brushed DC Speed Control with Back EMF (Back Electromotive Force) Feedback.

You may be aware that a brushed DC motor, when turned by hand, or by other means, will produce voltage at its leads, thus becoming a generator. When a brushed DC motor is being driven, and then the drive voltage is removed for a brief amount of time, the voltage generated by the inertia of the motor will be proportional to its speed. This voltage is the Back EMF. In this lab we will use the PWM mode of the Capture Compare PWM (CCP) module in the PIC16F887 Micro Controller, to create a hardware PWM to control the speed of the brushed DC motor on the Mechatronics Demo Board. We will measure the Back EMF off of the brushed DC motor, condition this signal via the Analog to Digital Converter (ADC) and adjust the motors speed using POT1 on the Mechatronics Demo Board, see figure 3.

Procedure:

1. Wire the Mechatronics board as shown in figure 2 and the Pic16F887 pin diagram on page 2. Use the supplied jumpers for the following connections:

- RD7 (J10) to P1 (J1)
- RC1 (J13) to N2 (J1)
- RA0 (J13) to POT1 (J4)
- RA1 (J13) to BACK EMF (J16)
- Attach the motor leads to DRIVE 1 (P9) and DRIVE 2 (P10).
- J2 and J3 should be unpopulated.
- Connect the right and center pins of JP8 using a shunt (two pin jumpers). This will put 5 volts across the brushed DC motor.

2. Make sure the ICD 2 programmer is connected to the USB cable and Mechatronics Demo Board via the ICD connector, at the lower left hand corner of the demo board. Next, connect the other 9volt power supply to the Mechatronics Demo Board and press the **CLR Fault button** at the bottom of the Demo Board next to the yellow light. The light will turn off after the button is pressed.

3. Also, connect the serial cable to the 9 pin serial connector at the upper left hand corner of the Mechatronics Demo Board. Then click the **Start** tab at the lower left hand corner of the windows screen. Under **Programs → Accessories → Communications** click on the **Hyper Terminal**. The New Connection window will appear. Type **Lab2** in the description box and click **OK**. In the next window select **COM1** then click **OK**. In the **Port Setup** window select; 9600 <u>baud rate, 8 data bits, Polarity None, Stop bits 1, and Flow control Hardware then</u> click **Apply** then **OK**.

4. Double click the **Masters folder** icon on the PC's desktop. Go into the **11080 BDC folder**, double click the **Labs folder**, and select **Lab2 folder**. Now, open **Lab2.mcw** workspace file and MPLAB IDE program will automatically open at the Lab2 workspace.

5. The Output window should indicate that ICD 2 connection has been established automatically and is ready. Also

the **Lab2.asm** program file will automatically appear in the MPLAB IDE Editor window.

6. Now, click the **<u>Project</u>** tab on the menu above. Then click **<u>Build All</u>**. The Output window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application. Next, click the **<u>Programmer</u>** tab on the menu bar above. Then click **<u>Program</u>**. The **Output** window will say "Programming succeeded, MPLAB ICD 2 Ready".

7. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

8. Now, the program is running and you can turn POT1 to adjust the speed of the brushed DC motor. Also, the speed of the brushed DC motor will appear inside the Hyper Terminal window.

<u>Note:</u>

Turn POT1 100% clockwise to run the motor at full speed. Next, run the motor at half speed by setting POT1 to 50%. Notice that the speed values shown in the Hyper Terminal will take a few seconds to stabilize. This is due to the Back EMF taking a few seconds to adjust. So, as you adjust the speed via POT1, give it a few seconds to stabilize before reading the speed. Also, make a mental note of speed value at 100% and at 50%.

9. Finally, unplug the 9volt power supply from the Mechatronics Demo Board. Then exit from MPLAB IDE. This is the end of Lab2.
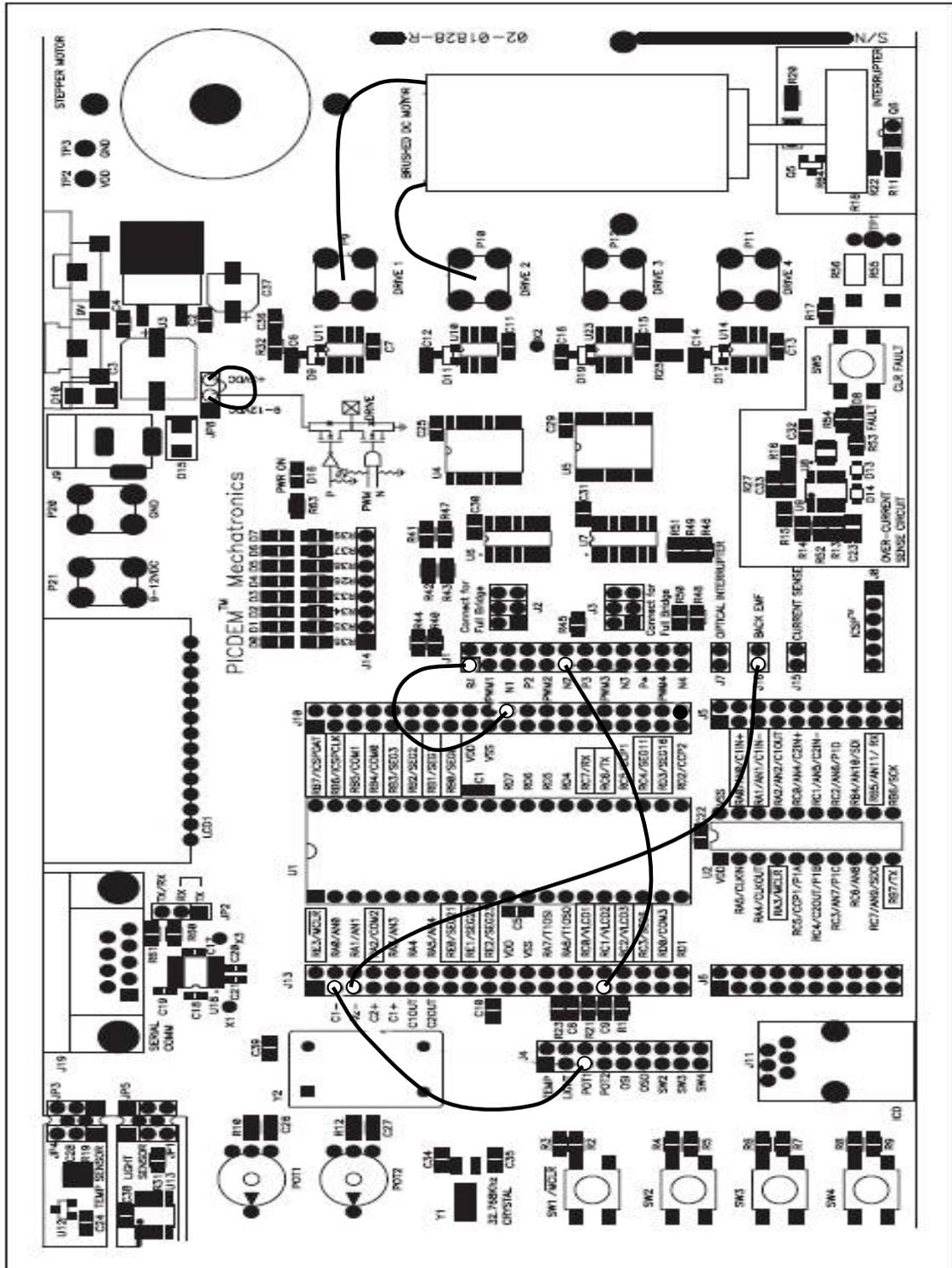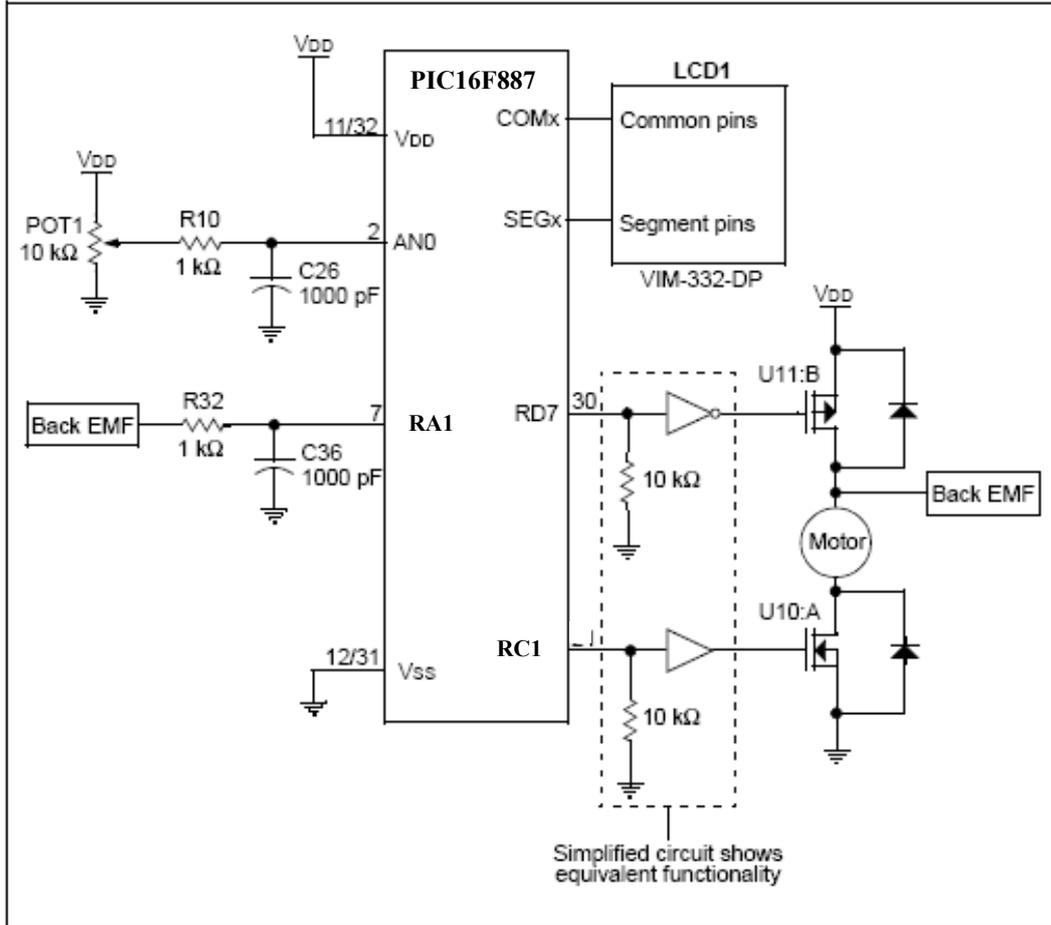
Figure 2. Jumper Diagram

Figure 3. Project Schematic.

Lab 3

Brushed DC Motor Speed Control with Optical Encoder Feedback.

Motor control is required in many Mechatronic applications ranging from power windows to washing machine cycle control. In this lab, the Capture Compare PWM (CCP) module will be used in PWM mode to generate a brushed DC motor drive. Timer 1 will measure speed feedback from the optical interrupter on the demo board. The optical interrupter circuit generates a high signal when light passes through the slots in the encoder disk. By measuring the time between pulses, the speed of the motor can be determined. A real-life application example includes precision speed control of a fan or hard disk drive, see figure 5.

Procedure:

1. Wire the Mechatronics board as shown in figure 4 and the Pic16F887 pin diagram on page 2. Use the supplied jumpers for the following connections:

- RD7 (J10) to P1 (J1)
- RC1 (J13) to N2 (J1)
- RA0 (J13) to POT1 (J4)
- RA1 (J13) to Optical Interrupter (J7)
- Attach the motor leads to DRIVE 1 (P9) and DRIVE 2 (P10).
- J2 and J3 should be unpopulated (no shunts present).
- Connect the right and center pins of JP8 using a shunt (two pin jumpers). This will put 5 volts across the brushed DC motor.

2. Make sure the ICD 2 programmer is connected to the USB cable and Mechatronics Demo Board via the ICD connector, at the lower left hand corner of the demo board. Next, connect the other 9volt power supply to the Mechatronics Demo Board and press the **CLR Fault button** at the bottom of the Demo Board next to the yellow light. The light will turn off after the button is pressed.

3. Also, connect the serial cable to the 9 pin serial connector at the upper left hand corner of the Mechatronics Demo Board. Then click the **Start** tab at the lower left hand corner of the windows screen. Under **Programs →Accessories → Communications** click on the **Hyper Terminal**. The New Connection window will appear. Type **Lab3** in the description box and click **OK**. In the next window select **COM1** then click **OK**. In the **Port Setup** window select; 9600 underline baud rate, 8 data bits, Polarity None, Stop bits 1, and Flow control Hardware then click **Apply** then **OK**.

4. Double click the **Masters folder** icon on the PC's desktop. Go into the **11080_BDC folder**, double click the **Labs folder**, and select **Lab3 folder**. Now, open **Lab3.mcw** workspace file and MPLAB IDE program will automatically open at the Lab3 workspace.

5. The Output window should indicate that ICD 2 connection has been established automatically and is ready. Also the **Lab3.asm** program file will automatically appear in the MPLAB IDE Editor window.

6. Now, click the **Project** tab on the menu above. Then click **Build All**. The Output window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application. Next, click the **Programmer** tab on the menu bar above. Then click **Program**. The **Output** window will say "Programming succeeded, MPLAB ICD 2 Ready".

7. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

8. Now, the program is running and you can turn POT1 to adjust the speed of the brushed DC motor. Now, the speed of the brushed DC motor will appear inside the Hyper Terminal window.

Note:

Turn POT1 100% clockwise to run the motor at full speed. Next, run the motor at half speed by setting POT1 to 50%. Notice that the speed values shown in the Hyper Terminal will take a few seconds to stabilize. How does the motor speed at 100% and 50% differ from the Back EMF lab, if any? The motor speed at 100% and 50% using the optical encoder should vary less than the motor speed at 100% and 50% using the Back EMF. Thus, the optical encoder will give you a more accurate motor speed measurement.

9. Finally, unplug the 9volt power supply from the Mechatronics Demo Board. Then exit from MPLAB IDE. This is the end of Lab3.

Figure 4. Jumper Diagram

Figure 5. Project Schematic.
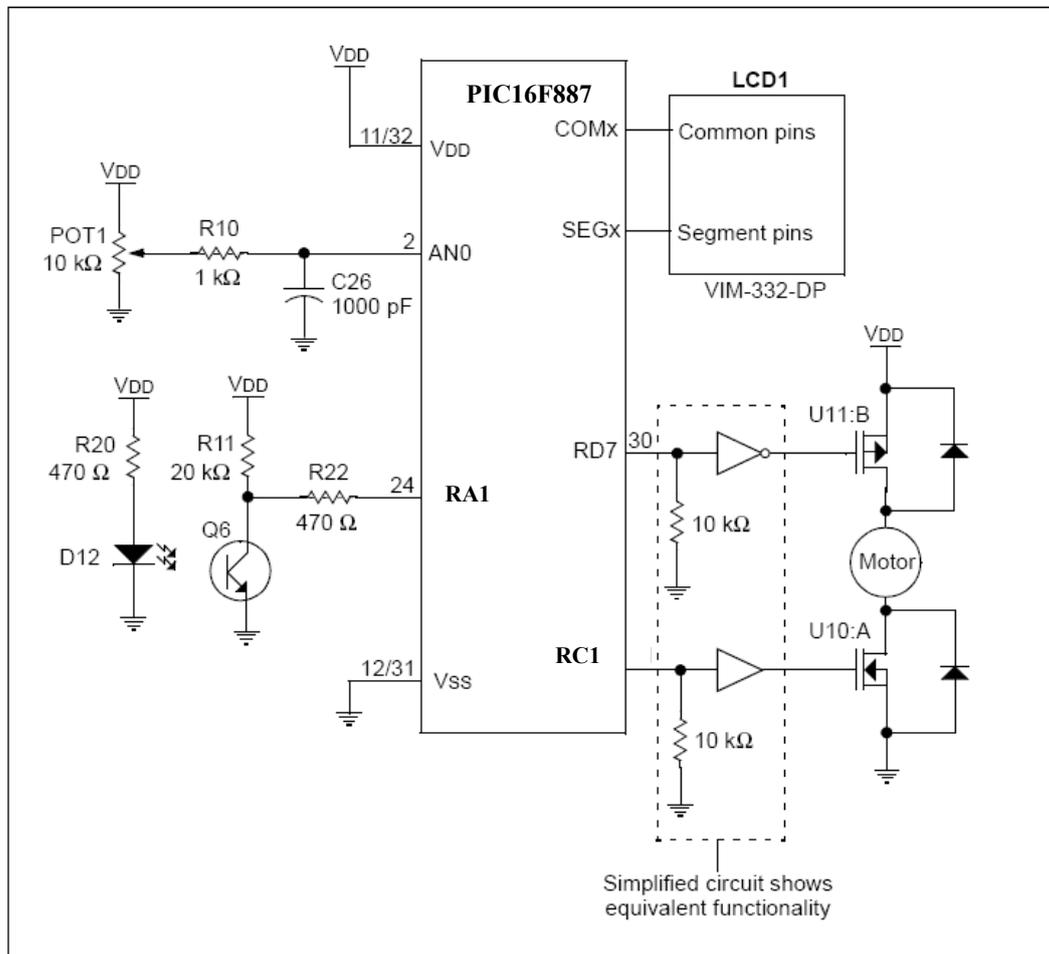
Lab 4

Brushed DC Motor Control Using the ECCP

This lab uses the Enhanced Capture Compare PWM (ECCP) module in the PIC16F887. In PWM mode, the ECCP module has two outputs for directly driving a full-bridge circuit in the forward or reverse directions. This makes implementing bidirectional speed control of a brushed DC motor a simple task. This lab also uses switch 2 (SW2) to simulate an event that would cause the motor to stop or change direction, see figure 7.

Procedure:

1. Wire the Mechatronics board as shown in figure 6 and the Pic16F887 pin diagram on page 2. Use the supplied jumpers for the following connections:

- P1A/RC2 (J13) to P1 (J1)
- P1B/RD5 (J10) to N1 (J1)
- P1C/RD6 (J10) to P2 (J1)
- P1D/RD7 (J10) to N2 (J1)
- AN1/RA1 (J13) to POT1 (J4)
- RC3 (J13) to SW2 (J4)
- Make sure there are no shunts (two pin jumpers) on J2 or J3.
- Attach the brushed DC motor leads to DRIVE 1 (P9) and DRIVE 2 (P10).
- Connect the right and center pins of JP8 using a shunt. This will put 5 volts across the brushed DC motor.

2. Make sure the ICD 2 programmer is connected to the USB cable and Mechatronics Demo Board via the ICD connector, at the lower left hand corner of the demo board. Next, connect the other 9volt power supply to the Mechatronics Demo Board and press the **CLR Fault button** at the bottom of the Demo Board next to the yellow light. The light will turn off after the button is pressed.

3. Double click the **Masters folder** icon on the PC's desktop. Go into the **11080_BDC folder**, double click the **Labs folder**, and select **Lab4 folder**. Now, open **Lab4.mcw** workspace file and MPLAB IDE program will automatically open at the Lab4 workspace.

4. The Output window should indicate that ICD 2 connection has been established automatically and is ready. Also the **Lab4.asm** program file will automatically appear in the MPLAB IDE Editor window.

5. Now, click the **Project** tab on the menu above. Then click **Build All**. The Output window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application. Next, click the **Programmer** tab on the menu bar above. Then click **Program**. The **Output** window will say "Programming succeeded, MPLAB ICD 2 Ready".

6. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

7. Press Switch 2 (SW2) once and the brushed DC motor will turn on in the forward (clockwise) direction. Press SW2 a second time and the motor will stop. Press SW2 a third time and the motor will turn on in the reverse (counter-clockwise) direction. Press SW2 a forth time and the motor will stop. This sequence will continue as long as you press SW2.

Note:

While the motor is on, in the forward or reverse directions, you can vary the speed using POT1.

8. Finally, unplug the 9volt power supply from the Mechatronics Demo Board. Then exit from MPLAB IDE. This is the end of Lab4.
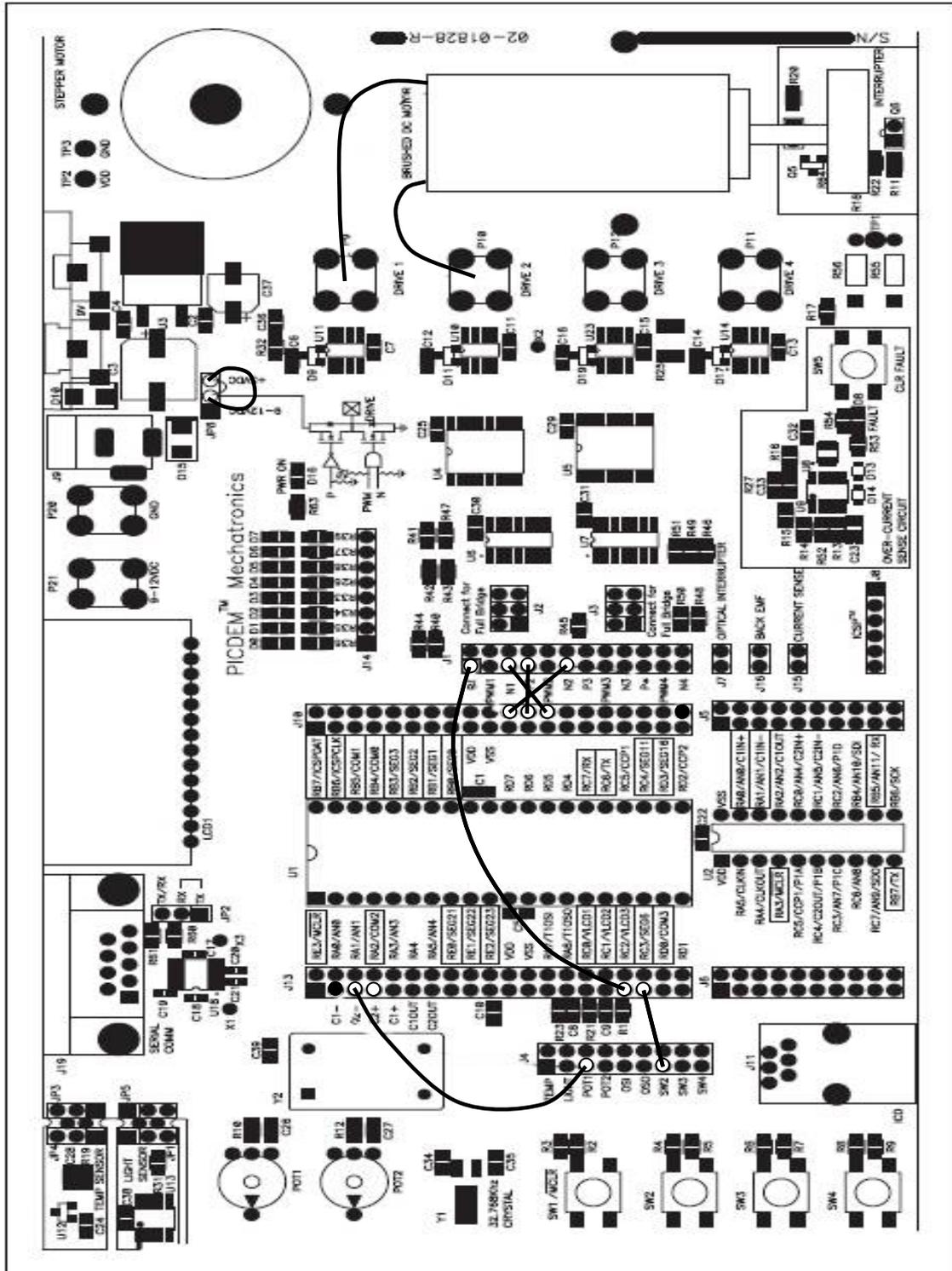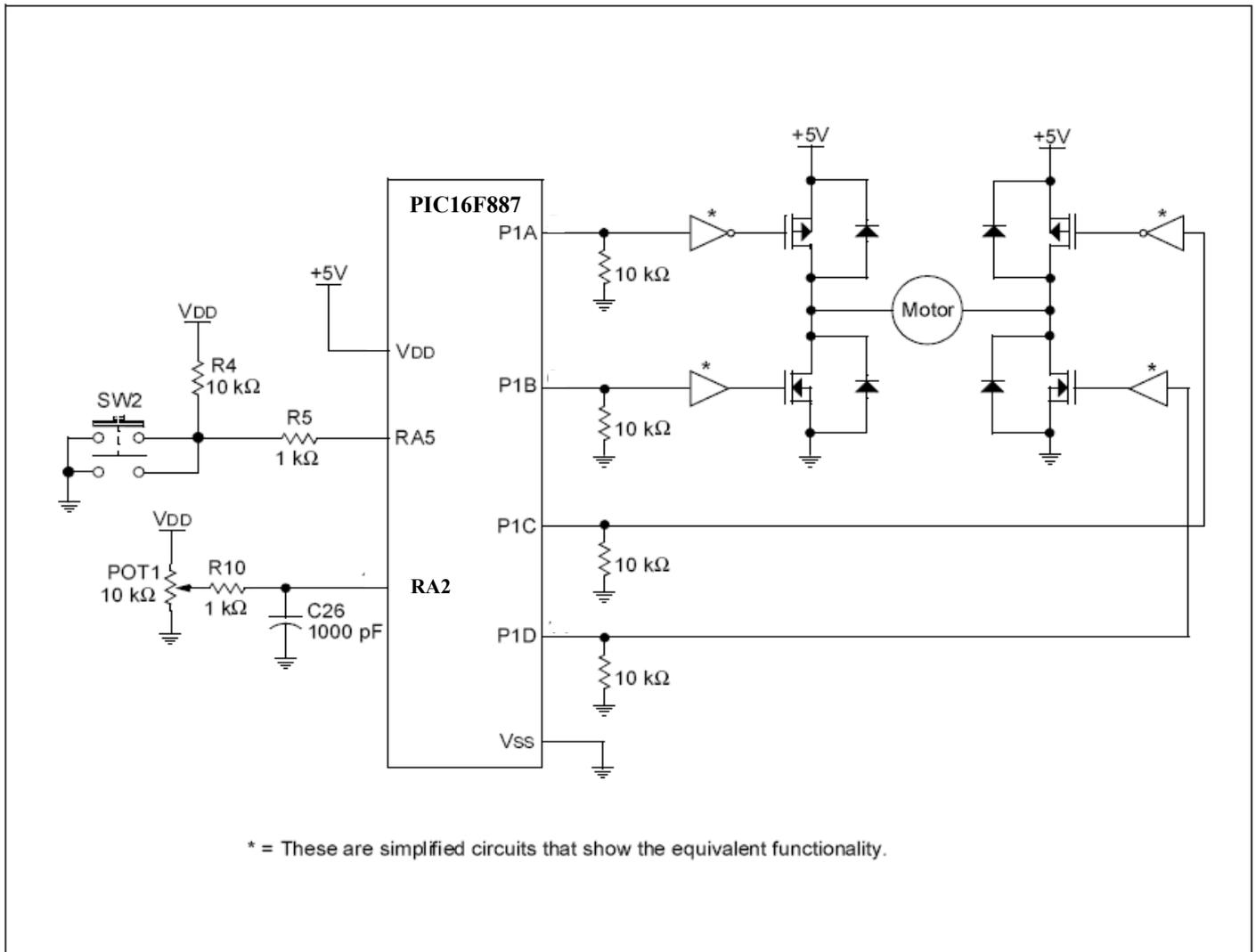
Figure 6. Jumper Diagram

Figure 7. Project Schematic.

Lab 5

Brushed DC Motor Control Using the ECCP and Current Sensing to detect loading.

This lab uses the Enhanced Capture Compare PWM (ECCP) module in the PIC16F887. In PWM mode, the ECCP module has two outputs for directly driving a full-bridge circuit in the forward or reverse directions. This lab also uses switch 2 (SW2) to simulate an event that would cause the motor to stop or change direction. However, if a load was to be placed on the motor (for example lifting a heavy object) the current through the motor will increase. Therefore, a current sensing circuit will prevent damage to the motor drive circuit by limiting current to the motor by shutting it down via the ECCP's Auto-shutdown and restarting the motor via the Auto-restart features.

Part 1:

Procedure:

1. Wire the Mechatronics board as shown in figure 8 and the Pic16F887 pin diagram on page 2. Use the supplied jumpers for the following connections:

- P1A/RC2 (J13) to P1 (J1)
- P1B/RD5 (J10) to N1 (J1)
- P1C/RD6 (J10) to P2 (J1)
- P1D/RD7 (J10) to N2 (J1)
- RA1 (J13) to POT1 (J4)
- RA3 (J13) to POT2 (J4)
- RC3 (J13) to SW2 (J4)
- Current Sensor (J15) to RB1 (J10)
- RB2 (J10) to SW3 (J4)
- Make sure there are no shunts (two pin jumpers) on J2.
- Attach the brushed DC motor leads to DRIVE 1 (P9) and DRIVE 2 (P10).
- Connect the right and center pins of JP8 using a shunt. This will put 5 volts across the brushed DC motor.

2. Make sure the ICD 2 programmer is connected to the USB cable and Mechatronics Demo Board via the ICD connector, at the lower left hand corner of the demo board. Next, connect the other 9volt power supply to the Mechatronics Demo Board and press the **CLR Fault button** at the bottom of the Demo Board next to the yellow light. The light will turn off after the button is pressed.

3. Double click the **Masters folder** icon on the PC's desktop. Go into the **11080_BDC folder**, double click the **Labs folder**, and select **Lab5 folder**. Now, open **Lab5.mcw** workspace file and MPLAB IDE program will automatically open at the Lab5 workspace.

4. The **Output** window should indicate that ICD 2 connection has been established automatically and is ready. Also the **Lab5.asm** program file will automatically appear in the **MPLAB IDE Editor** window.

5. Now, click the **Project** tab on the menu above. Then click **Build All**. The **Output** window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application.

Next, click the **Programmer** tab on the menu bar above. Then click **Program**. The **Output** window will say "Programming succeeded, MPLAB ICD 2 Ready".

6. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

7. Rotated POT2 counterclockwise all the way, rotated POT1 clockwise all the way, then press Switch 2 (SW2) once and the brushed DC motor will turn on in the forward (clockwise) direction. If the motor doesn't turn on, press SW3 once then press SW2 again and the motor should turn on. Press SW2 a second time and the motor will stop. Press SW2 a third time and the motor will turn on in the reverse (counter-clockwise) direction. Press SW2 a forth time and the motor will stop. This sequence will continue as long as you press SW2.

Note:

While the motor is on, in the forward or reverse directions, you can vary the speed using POT1. POT2 varies the resistance/load on the motor such that the motor current will increase or decrease. Thus, turning POT2 counterclockwise will decrease current through the motor and turning it clockwise will increase current.

8. Now, we will simulate a load on the motor by rotating POT2 clockwise, slowly until the motor turns off. When this happens, the current through the motor has reached the current limiting point of the current sensor, thus the Auto-shutdown feature shuts the motor off. Next, turn POT2 counterclockwise all the way and press SW3 once. This will clear the shutdown event in the ECCPAS register and the motor will turn on.

9. Finally, unplug the 9volt power supply from the Mechatronics Demo Board. Then exit from MPLAB IDE. This is the end of Lab5, Part 1.

Figure 8. Jumper Diagram

Part 2:

Procedure:

1. Wire the Mechatronics board as shown in figure 9 and the Pic16F887 pin diagram on page 2. Use the supplied jumpers for the following connections:

- P1A/RC2 (J13) to P1 (J1)
- P1B/RD5 (J10) to N1 (J1)
- P1C/RD6 (J10) to P2 (J1)
- P1D/RD7 (J10) to N2 (J1)
- RA1 (J13) to POT1 (J4)
- RA3 (J13) to POT2 (J4)
- RC3 (J13) to SW2 (J4)
- Current Sensor (J15) to RB1 (J10)
- Make sure there are no shunts (two pin jumpers) on J2 or J3.
- Attach the brushed DC motor leads to DRIVE 1 (P9) and DRIVE 2 (P10).
- Connect the right and center pins of JP8 using a shunt. This will put 5 volts across the brushed DC motor.

2. Make sure the ICD 2 programmer is connected to the USB cable and Mechatronics Demo Board via the ICD connector, at the lower left hand corner of the demo board. Next, connect the other 9volt power supply to the Mechatronics Demo Board and press the **CLR Fault button** at the bottom of the Demo Board next to the yellow light. The light will turn off after the button is pressed.

3. Double click the **Masters folder** icon on the PC's desktop. Go into the **11080_BDC folder**, double click the **Labs folder**, and select **Lab5 folder**. Now, open **Lab5_AR.mcw** workspace file and MPLAB IDE program will automatically open at the Lab5_AR workspace.

4. The **Output** window should indicate that ICD 2 connection has been established automatically and is ready. Also the **Lab5_AR.asm** program file will automatically appear in the **MPLAB IDE Editor** window.

5. Now, click the **Project** tab on the menu bar above. Then click **Build All**. The **Output** window will say "Build Succeeded", this means the program assembled correctly and you are ready to run the application. Next, click the **Programmer** tab on the menu bar above. Then click **Program**. The **Output** window will say "Programming succeeded, MPLAB ICD 2 Ready".

6. Unplug the ICD 2 cable from the ICD 2 connector at the lower left hand corner of the Mechatronics Demo Board.

7. Rotated POT2 counterclockwise all the way, rotated POT1 clockwise all the way, then press Switch 2 (SW2) once and the brushed DC motor will turn on in the forward (clockwise) direction. Press SW2 a second time and the motor will stop. Press SW2 a third time and the motor will turn on in the reverse (counter-clockwise) direction. Press SW2 a forth time and the motor will stop. This sequence will continue as long as you press SW2.

Note:

While the motor is on, in the forward or reverse directions, you can vary the speed using POT1. POT2 varies the resistance/load on the motor such that the motor current will increase or decrease. Thus, turning POT2 counterclockwise will decrease current through the motor and turning it clockwise will increase current.

8. Now, we will simulate a load on the motor by rotating POT2 clockwise, slowly until the motor turns off. When this happens, the current through the motor has reached the current limiting point of the current sensor, thus the Auto-shutdown feature shuts the motor off. Next, turn POT2 counterclockwise all the way and the Auto-restart feature will clear the shutdown event in the ECCPAS register and the motor will turn on.

9. Finally, unplug the 9volt power supply from the Mechatronics Demo Board. Then exit from MPLAB IDE. This is the end of Lab5, Part 2.

Figure 9. Jumper Diagram