Implementing a Simple Serial Mouse Controller

INTRODUCTION

The mouse is becoming increasingly popular as a standard pointing data entry device. It is no doubt that the demand of the mouse is increasing. Various kinds of mice can be found in the market, including optical mouse, opto-mechanical mouse, and its close relative, trackball. The mouse interfaces to the host via an RS-232 port or a dedicated interface card. Their mechanisms are very similar. The major electrical components of a mouse are:

- Microcontroller
- Photo-transistors
- Infrared emitting diode
- Voltage conversion circuit

The intelligence of the mouse is provided by the microcontroller, hence the features and performance of a mouse is greatly related to the microcontroller used.

This application note describes the implementation of a serial mouse using the PIC16C54. The PIC16C54 is a high speed 8-bit CMOS microcontroller offered by Microchip Technology Inc. It is an ideal candidate for a mouse controller.

THEORY OF OPERATION

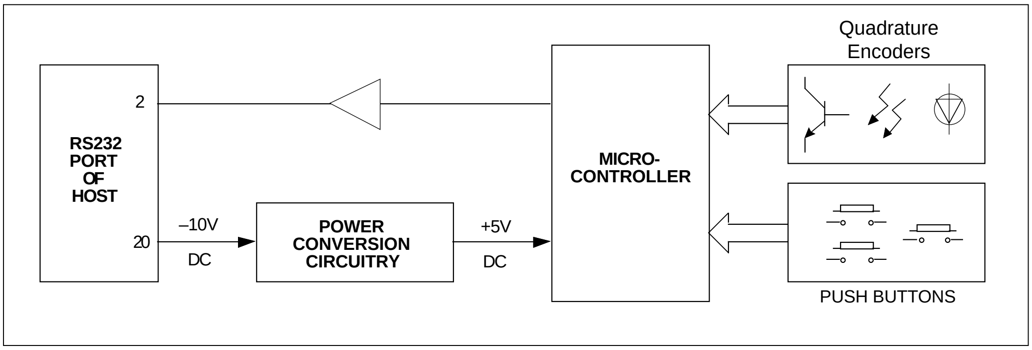
A mouse can be divided into several functional blocks:

- Microcontroller
- Button detection
- Motion detection
- RS-232 signal generation
- 5V DC power supply unit

A typical functional block diagram is shown in Figure 1.

In Figure 2, three push buttons are connected to the input ports of the PIC16C54. When a switch opening or closure is detected, a message is formatted and sent to the host. The X and Y movements are measured by counting the pulses generated by the photo-couplers. In the case of an opto-mechanical mouse, the infrared light emitted by the infrared diode is blocked by the rotating wheel, so that the pulses are generated on the photo-transistor side. In case of an optical mouse, the infrared light emitted by the infrared diode is reflected off the reflective pad patterned with vertical and horizontal grid lines. It is then received by the photo-transistor in the mouse. When any X or Y movement is detected, a message is formatted and sent to the host.

FIGURE 1 - FUNCTIONAL BLOCKS OF A SERIAL MOUSE



The Microsoft® Mouse System and the Mouse Systems® device both use serial input techniques. The Mouse System protocol format contains five bytes of data. One byte describes the status of three push buttons, two bytes for the relative X movements and two bytes for the relative Y movements. The Microsoft protocol format contains three bytes of data describing the status of two push buttons and the relative X and Y movements. The details of these protocols are given in Table 1.

Three lines are connected to the host via the RS-232 port:

- Signal Ground
- Received Data
- Request to Send

"Received Data" carries the message sent by the mouse. While "Request to Send" provides a –10V DC for voltage conversion circuitry. A voltage of +5V DC is required for electronic components inside the mouse, however, +5V DC is not part of an RS-232 port, so voltage conversion circuitry is required. This circuit is typically composed of a 555 timer, Zener diodes, and capacitors. An example circuit is shown in Figure 3. Since the current supplied through the RS-232 port is limited to 10 mA, the mouse cannot be designed to consume more than 10 mA current unless an external power supply is provided. The PIC16C54, running at 4 MHz (1 µs instruction cycle) can provide a very high tracking speed. An 8 MHz version of PIC16C54 is also available if higher performance is desired.

FIGURE 2 - PIC16C54 PIN ASSIGNMENT

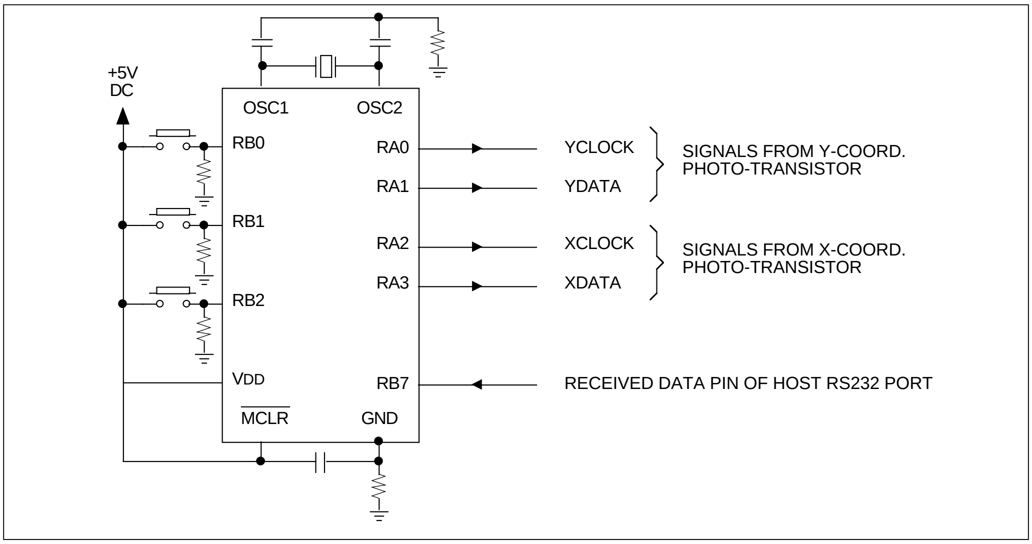
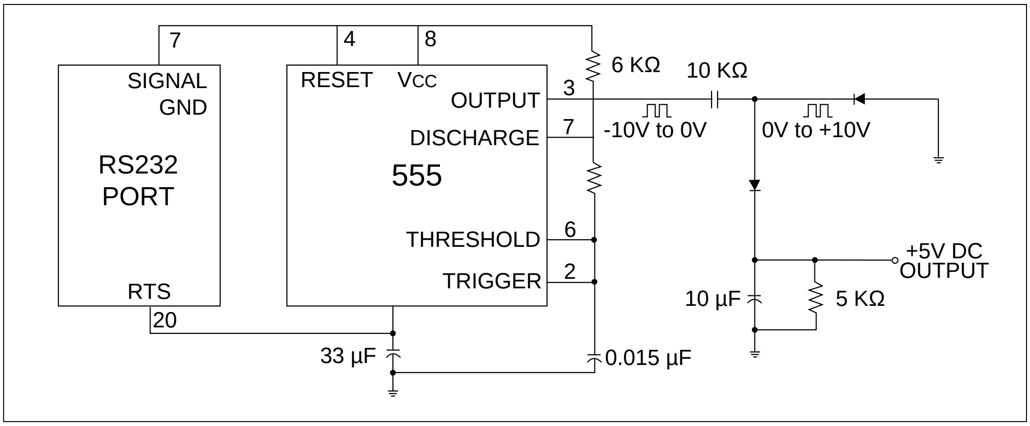

+5V DC
OSC1
OSC2
RB0
RB1
RB2
VDD
MCLR
GND
RA0
RA1
RA2
RA3
RB7
YCLOCK
YDATA
SIGNALS FROM Y-COORD. PHOTO-TRANSISTOR
XCLOCK
XDATA
SIGNALS FROM X-COORD. PHOTO-TRANSISTOR
RECEIVED DATA PIN OF HOST RS232 PORT

FIGURE 3 - VOLTAGE CONVERSION CIRCUITRY



ABOUT THE SOFTWARE

The major tasks performed by the software are button scanning, X and Y motion scanning, formatting and sending serial data to the host. These tasks need to be performed in parallel in order to gain better tracking speed. The pulses generated by the photo-couplers are counted while transmitting the serial signals to the RS-232 port. The number of pulses reflects the speed of the movement. The more number of pulses, the faster the movement is.

The directions of the movement are determined by the last states and the present states of the outputs of the photo-transistors. In Figure 4, XCLOCK and XDATA are outputs from the photo-transistors corresponding to the X-axis movement. XDATA is read when a rising or a falling edge of XCLOCK is detected. For right movement, XDATA is either LOW at the rising edge of XCLOCK or HIGH at the falling edge of XCLOCK. The up and down movement detections follow the same logic. In Table 1, X7:X0 are data for relative movement. If X is positive, it implies that the mouse is moving to the right. If X is negative, it implies a movement to the left. Similarly, if Y is positive, it indicates that the mouse is moving down and if Y is negative, it indicates that the mouse is moving up. The pulses generated by the photo-couplers are checked before every bit is sent. A bit takes 1/1200 second to send, if the distance between the grid lines is 1 mm, the tracking speed will be up to 1200 mm/second.

FIGURE 4 - VOLTAGE CONVERSION CIRCUITRY

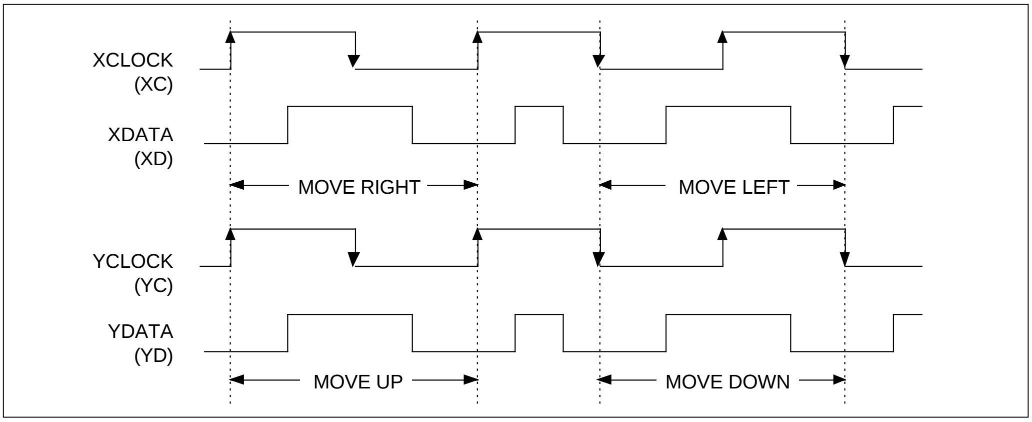


TABLE 1 - MOUSE SYSTEM AND MICROSOFT PROTOCOLS

	Mouse System Format*								Microsoft Format*							
Bit Position	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Byte 1	1	0	0	0	0	L	M	R	1	1	L	R	Y7	Y6	X7	X6
Byte 2	X7	X6	X5	X4	X3	X2	X1	X0	0	0	X5	X4	X3	X2	X1	X0
Byte 3	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0	0	0	Y5	Y4	Y3	Y2	Y1	Y0
Byte 4	X7	X6	X5	X4	X3	X2	X1	X0								
Byte 5	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0								

***** L = Left Key Status	1 = Pressed	X7-X0 = X-Axis Movement Data
M = Middle Key Status	0 = Released	Y7-Y0 = Y-Axis Movement Data
R = Right Key Status		

The buttons are scanned after a message is sent and the time used to send the message is used as the debouncing time. The message is in an RS-232 format with 1200 baud, eight data bits, no parity, and two stop bits.

The flow charts of the main program, subroutine BYTE and subroutine BIT are shown in Figures 5, 6, and 7. Figure 5 shows the Trigger Flag is set when any change of button status or X/Y movement is detected. Subroutine BYTE is called in the main program five times to send five bytes of information. Subroutine BYTE controls the status of the “Received Data” (RD) pin. If Trigger Flag is clear, RD will always be HIGH. Hence, no message will be sent even when subroutine BYTE is called. Figure 7 shows that subroutine BIT counts the number of pulses from outputs of the photo-transistors, determines the directions, and generates 1/1200 second delay to get 1200 baud timing.

The mouse has been tested in Mouse System Mode and is functioning properly. A completed listing of the source program is given in Appendix A.

SUMMARY

The PIC16C54 from Microchip Technology Inc. provides a very cost-effective, high performance mouse implementation. Its low power (typically < 2 mA at 1 µs instruction cycle), small package (18-pin) and high reliability (on-chip watchdog timer to prevent software hang-ups) are among several reasons why the PIC16C54 is uniquely suitable for mouse applications.

This application note provides the user with a simple, fully functional serial mouse implementation. The user may use this as a starting point for a more comprehensive design. For fully implemented and compliant mouse products see Microchip's ASSP device family (MTA41XXX).

FIGURE 5 - FLOW CHART OF THE MAIN PROGRAM

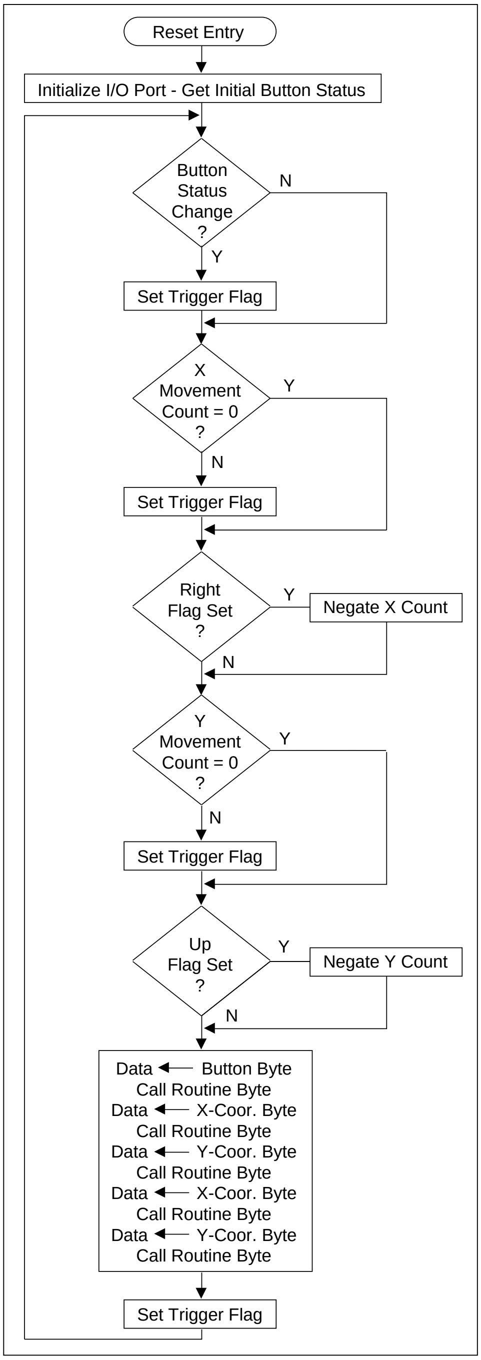


FIGURE 6 - FLOW CHART OF ROUTINE BYTE

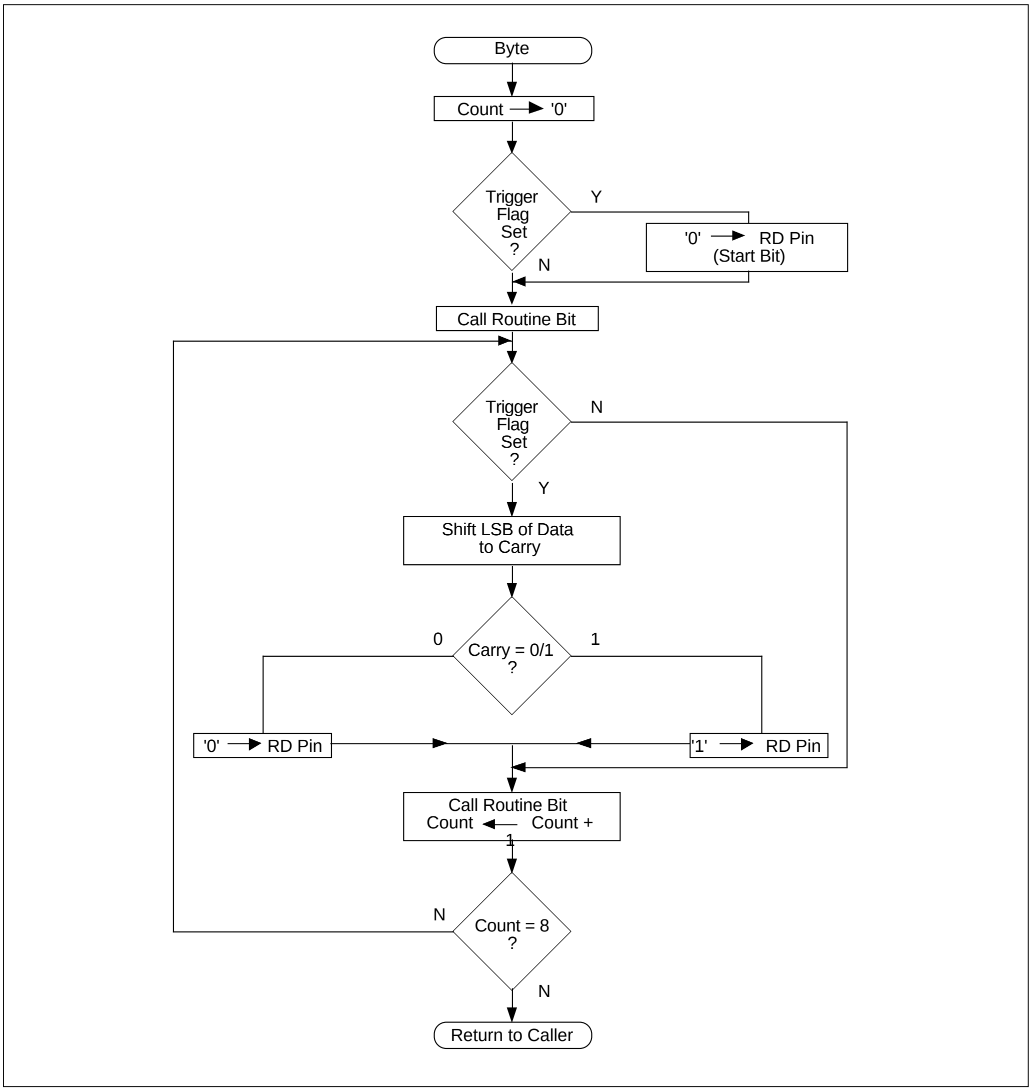
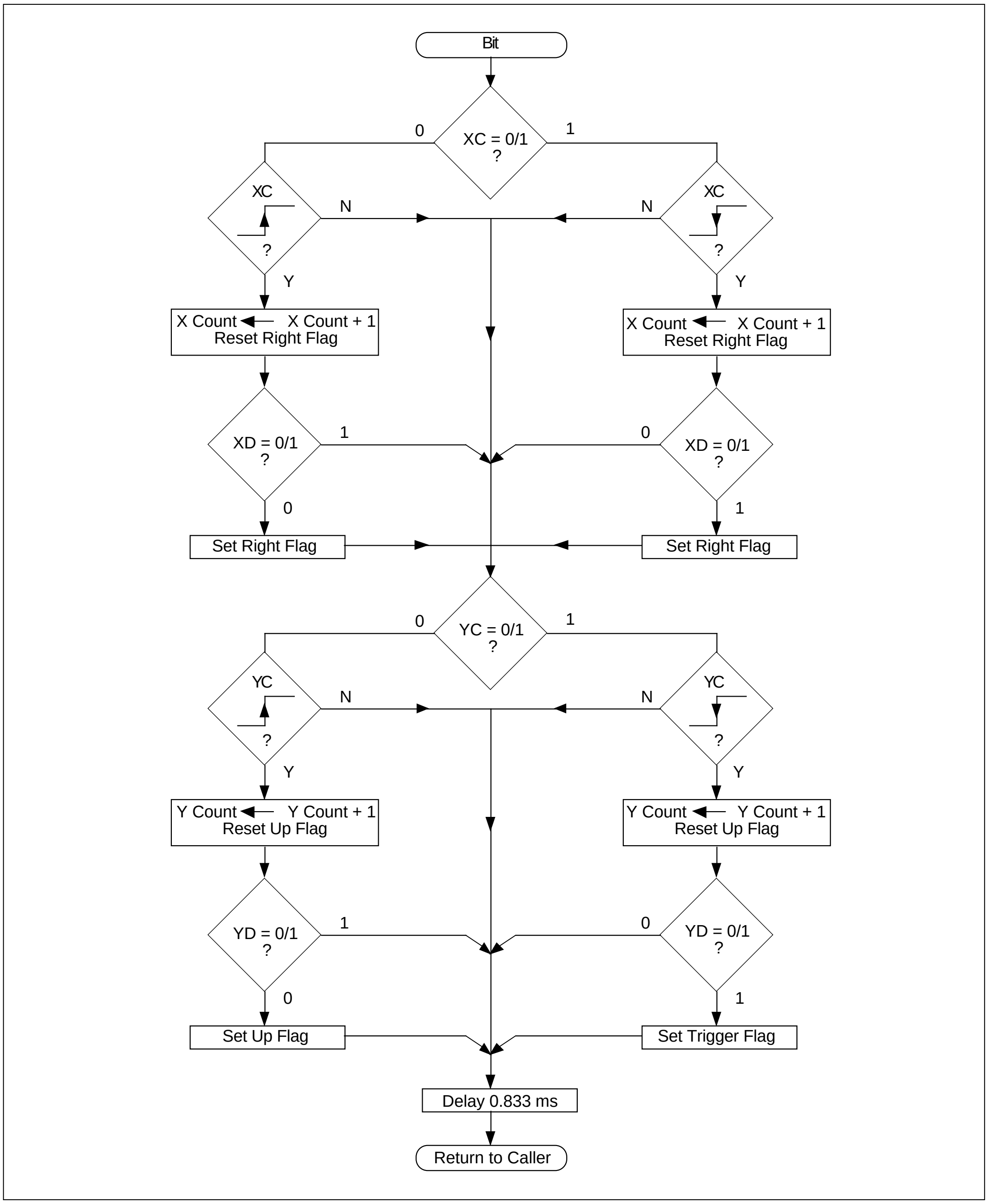


FIGURE 7 - FLOW CHART OF ROUTINE BIT



APPENDIX A:

```
MPASM B0.54                                                                PAGE  1
 MOUSE

                     TITLE " MOUSE "
                      LIST   P=16C54,R=O
                     ;
                     ;*******************************************
                     ;*                                         *
                     ;*   MOUSE CONTROLLER                      *
                     ;*                                         *
                     ;*   VERSION : 25 APRIL, 1990              *
                     ;*                                         *
                     ;*   MODE = PIC16C54XT   CLK=4.0MHZ    *
                     ;*******************************************
                     ;
                     ;______________________
                     ;       FILES ASSIGNMENT
                     ;______________________
                     ;
0003                 STATUS       EQU 3            ;STATUS REGISTER
0005                 RA           EQU 5            ;I/O PORT A
0006                 RB           EQU 6            ;I/O PORT B
0008                 TIMER1       EQU 10           ;COUNTER FOR DELAY
000C                 CSTAT        EQU 14           ;CO-ORDINATE STATUS
000D                 BSTAT        EQU 15           ;BUTTON STATUS
000E                 DATA0        EQU 16           ;
000F                 DATA1        EQU 17           ;
0010                 DATA2        EQU 20           ;5 BYTE RS232 DATA
0011                 DATA3        EQU 21           ;
0012                 DATA4        EQU 22           ;
0013                 FLAGA        EQU 23           ;GENERAL PURPOSE FLAG
0014                 XCOUNT       EQU 24           ;X-MOVEMENT COUNTER
0015                 YCOUNT       EQU 25           ;Y-MOVEMENT COUNTER
0016                 FLAGB        EQU 26           ;GENERAL PURPOSE FLAG
0018                 COUNT        EQU 30           ;GENERAL PURPOSE COUNTER
0019                 DATA_AREA    EQU 31           ;FOR TEMP. STORAGE
                     ;
                     ;______________________
                     ;       BIT ASSIGNMENT
                     ;______________________
                     ;
0000                 YC           EQU 0            ;Y-CLOCK PIN
0001                 YD           EQU 1            ;Y-DATA PIN
0001                 UP           EQU 1            ;MOVING UP FLAG
0002                 XC           EQU 2            ;X-CLOCK PIN
0003                 XD           EQU 3            ;X-DATA PIN
0003                 RI           EQU 3            ;MOVING RIGHT FLAG
0000                 BU1          EQU 0            ;BUTTON #1 PIN
0002                 BU2          EQU 2            ;BUTTON #2 PIN
0000                 CA           EQU 0            ;CARRY FLAG
0007                 RD           EQU 7            ;RECEIVED DATA PIN TO RS232
0002                 ZERO_AREA    EQU 2            ;ZERO FLAG
0002                 TR           EQU 2            ;TIGGER FLAG
                     ;
                     ;===========================================
                     ;       SUBROUTINES
                     ;===========================================
                     ;
                     ;*******************************************
                      ORG 0
                     ;*******************************************
                     ;
                     ;===========================================
                     ; DELAY A BIT TIME AND CHECK XC & YC STATUS
                     ;===========================================
                     BIT
0000 0745                 BTFSS    RA,XC            ;XC = 1 ?
0001 0A0A                 GOTO     BIT0
0002 064C                 BTFSC    CSTAT,XC         ;(XC=1)
0003 0A11                 GOTO     BITY             ;(XC ALWAYS = 1)
0004 02B4                 INCF     XCOUNT           ;(XC —|__)
0005 0476                 BCF      FLAGB,RI         ;DEFAULT LEFT
0006 0765                 BTFSS    RA,XD            ;LEFT / RIGHT ?
0007 0A11                 GOTO     BITY
0008 0576                 BSF      FLAGB,RI
0009 0A11                 GOTO     BITY
                     BIT0
000A 074C                 BTFSS    CSTAT,XC         ;(XC=0)
000B 0A11                 GOTO     BITY             ;(XC ALWAYS = 0)
000C 02B4                 INCF     XCOUNT           ;(XC __|—)
000D 0476                 BCF      FLAGB,RI         ;DEFAULT LEFT
000E 0665                 BTFSC    RA,XD            ;LEFT / RIGHT ?
000F 0A11                 GOTO     BITY
0010 0576                 BSF      FLAGB,RI
                     BITY
0011 0705                 BTFSS    RA,YC            ;YC = 1 ?
0012 0A1B                 GOTO     BITY0
0013 060C                 BTFSC    CSTAT,YC         ;(YC=1)
0014 0A22                 GOTO     BITDY            ;(YC ALWAYS = 1)
0015 02B5                 INCF     YCOUNT           ;(YC —|__)
0016 0436                 BCF      FLAGB,UP         ;DEFAULT DOWN
0017 0725                 BTFSS    RA,YD            ;DOWN / UP ?
0018 0A22                 GOTO     BITDY
0019 0536                 BSF      FLAGB,UP
001A 0A22                 GOTO     BITDY
                     BITY0
001B 070C                 BTFSS    CSTAT,YC         ;(YC=0)
001C 0A22                 GOTO     BITDY            ;(YC ALWAYS = 0)
001D 02B5                 INCF Y   COUNT            ;(YC __|—)
001E 0436                 BCF      FLAGB,UP         ;DEFAULT DOWN
001F 0625                 BTFSC    RA,YD            ;DOWN / UP ?
0020 0A22                 GOTO     BITDY
0021 0536                 BSF      FLAGB,UP
                     BITDY
0022 0205                 MOVF     RA,W             ;SAVE COOR. STATUS
0023 002C                 MOVWF    CSTAT
0024 0CC1                 MOVLW    193D             ;0.833 MS DELAY
0025 0028                 MOVWF    TIMER1
                     BITD0
0026 0000                 NOP
0027 02E8                 DECFSZ   TIMER1
0028 0A26                 GOTO     BITD0
0029 0800                 RETLW    0
                     ;
                     ;==================================================
                     ;
                     ;**************************************************
                     ;*      SUBROUTINE TO SEND A BYTE                 *
                     ;*      AS RS232C FORMAT 8,N,1                    *
                     ;**************************************************
                     ;
                     BYTE
002A 0078                 CLRF     COUNT            ;RESET 8 BIT COUNT
002B 0753                 BTFSS    FLAGA,TR         ;ANY TRIGGER
002C 0A2E                 GOTO     BYTE0
002D 04E6                 BCF      RB,RD            ;LOW RD FOR START BIT
                     BYTE0
002E 0900                 CALL     BIT
                     BYTE1
002F 0753                 BTFSS    FLAGA,TR         ;ANY TRIGGER ?
0030 0A37                 GOTO     BYTE3
0031 0339                 RRF      DATA_AREA        ;SHIFT DATA TO CARRY
0032 0703                 BTFSS    STATUS,CA        ;0 / 1 ?
0033 0A36                 GOTO     BYTE2
```

```
0034 05E6                BSF     RB,RD              ;SEND A 1
0035 0A37                GOTO    BYTE3
                    BYTE2
0036 04E6                BCF     RB,RD              ;SEND A 0
                    BYTE3
0037 0900                CALL    BIT
0038 02B8                INCF    COUNT
0039 0778                BTFSS   COUNT,3            ;COUNT = 8 ?
003A 0A2F                GOTO    BYTE1
003B 0753                BTFSS   FLAGA,TR           ;ANY TRIGGER ?
003C 0A42                GOTO    BYTE4
003D 04E6                BCF     RB,RD              ;SEND SENT BIT
003E 0900                CALL    BIT
003F 05E6                BSF     RB,RD
0040 0900                CALL    BIT
0041 0A44                GOTO    BYTE5
                    BYTE4
0042 0900                CALL    BIT
0043 0900                CALL    BIT
                    BYTE5
0044 0800                RETLW   0
                    ;
                    ;============================================
                    ;       RESET ENTRY
                    ;============================================
                    ;
                    INIT
0045 0CC1                MOVLW   B’11000001'        ;DISABLE WATCH DOG
0046 0002                OPTION
0047 0C0F                MOVLW    B’00001111'       ;INIT RB0~3 BE INPUTS
0048 0006                TRIS RB                     ;RB4~7 BE OUTPUTS
0049 0CFF                MOVLW   B’11111111'        ;INIT RA0~3 BE INPUTS
004A 0005                TRIS    RA
004B 05E6                BSF     RB,RD              ;HIGH RD PIN
004C 0246                COMF    RB,W               ;GET INIT BUTTON INPUTS
004D 0E05                ANDLW   B’00000101'
004E 0D80                IORLW   B’10000000'
004F 002D                MOVWF   BSTAT
0050 002E                MOVWF   DATA0
0051 0205                MOVF    RA,W
0052 002C                MOVWF   CSTAT
0053 0073                CLRF    FLAGA              ;CLEAR TR FLAG
0054 0074                CLRF    XCOUNT             ;RESET XCOUNT & YCOUNT
0055 0075                CLRF    YCOUNT
                    SCAN
0056 006F                CLRF    DATA1              ;UPDATE X,Y MOVEMENT DATA
0057 0070                CLRF    DATA2
0058 0071                CLRF    DATA3
0059 0072                CLRF    DATA4
005A 0214                MOVF    XCOUNT,W           ;XCOUNT = 0 ?
005B 0743                BTFSS   STATUS,ZERO_AREA
005C 0A80                GOTO    WRITX
                    SCANA
005D 0215                MOVF Y  COUNT,W            ;YCOUNT = 0 ?
005E 0743                BTFSS   STATUS,ZERO_AREA
005F 0A92                GOTO    WRITY
                    SCANB
0060 0246                COMF    RB,W               ;BUTTON STATUS CHANGE ?
0061 0E05                ANDLW   B’00000101'
0062 0D80                IORLW   B’10000000'
0063 00AD                SUBWF   BSTAT
0064 0643                BTFSC   STATUS,ZERO_AREA   ;IF CHANGE THEN TRIGGER
0065 0A6B                GOTO    SCANC              ;(NO CHANGE)
0066 0553                BSF     FLAGA,TR           ;(CHANGE) SET TRIGGER FLAG
0067 0246                COMF    RB,W               ;FORMAT BUTTON STATUS DATA
0068 0E05                ANDLW   B’00000101'
0069 0D80                IORLW   B’10000000'
```

```
006A 002E                    MOVWF   DATA0
                        SCANC
006B 0246                    COMF    RB,W
006C 0E05                    ANDLW   B’00000101'
006D 0D80                    IORLW   B’10000000'
006E 002D                    MOVWF   BSTAT
006F 020E                    MOVF    DATA0,W           ;SEND DATA0,1,2,3,4 TO HOST
0070 0039                    MOVWF   DATA_AREA
0071 092A                    CALL    BYTE
0072 020F                    MOVF    DATA1,W
0073 0039                    MOVWF   DATA_AREA
0074 092A                    CALL    BYTE
0075 0210                    MOVF    DATA2,W
0076 0039                    MOVWF   DATA_AREA
0077 092A                    CALL    BYTE
0078 0211                    MOVF    DATA3,W
0079 0039                    MOVWF   DATA_AREA
007A 092A                    CALL    BYTE
007B 0212                    MOVF    DATA4,W
007C 0039                    MOVWF   DATA_AREA
007D 092A                    CALL    BYTE
007E 0453                    BCF     FLAGA,TR          ;CLEAR TRIGGER FLAG
007F 0A56                    GOTO    SCAN
                        ;
                        WRITX
0080 0553                    BSF     FLAGA,TR          ;SET TRIGGER FLAG
0081 0C40                    MOVLW   40H               ;IF XCOUNT > 64 THEN XCOUNT <-64
0082 0094                    SUBWF   XCOUNT,W
0083 0603                    BTFSC   STATUS,CA
0084 0A8D                    GOTO    WRITR
                        WRITS
0085 0776                    BTFSS   FLAGB,RI          ;LEFT / RIGHT ?
0086 0A90                    GOTO    WRITL
0087 0274                    COMF    XCOUNT            ;(RIGHT) NEG XCOUNT
0088 0294                    INCF    XCOUNT,W
                        WRITA
0089 002F                    MOVWF   DATA1
008A 0031                    MOVWF   DATA3
008B 0074                    CLRF    XCOUNT            ;RESET XCOUNT
008C 0A5D                    GOTO    SCANA
                        ;
                        WRITR
008D 0C40                    MOVLW   40H               ;XCOUNT <- 64
008E 0034                    MOVWF   XCOUNT
008F 0A85                    GOTO    WRITS
                        ;
                        WRITL
0090 0214                    MOVF    XCOUNT,W          ;(LEFT)
0091 0A89                    GOTO    WRITA
                        ;
                        WRITY
0092 0553                    BSF     FLAGA,TR          ;SET TRIGGER FLAG
0093 0C40                    MOVLW   40H               ;IF YCOUNT > 64 THEN YCOUNT <-64
0094 0095                    SUBWF   YCOUNT,W
0095 0603                    BTFSC   STATUS,CA
0096 0A9F                    GOTO    WRITV
                        WRITW
0097 0736                    BTFSS   FLAGB,UP          ;DOWN / UP ?
0098 0AA2                    GOTO    WRITD
0099 0275                    COMF    YCOUNT            ;(UP) NEG YCOUNT
009A 0295                    INCF    YCOUNT,W
                        WRITB
009B 0030                    MOVWF   DATA2
009C 0032                    MOVWF   DATA4
009D 0075                    CLRF    YCOUNT            ;RESET YCOUNT
009E 0A60                    GOTO    SCANB
                        ;
```

```
                     WRITV
009F 0C40                 MOVLW   40H               ;YCOUNT <- 64
00A0 0035                 MOVWF   YCOUNT
00A1 0A97                 GOTO    WRITW
                     ;
                     WRITD
00A2 0215                 MOVF    YCOUNT,W          ;(DOWN)
00A3 0A9B                 GOTO    WRITB
                     ;
                     ;===========================================
                     ;       RESET ENTRY
                     ;===========================================
                     ;
                      ORG 777
01FF 0A45                 GOTO INIT                ;JUMP TO PROGRAM STARTING
                     ;
                     END
                     ;
                     ;********************************************


Errors   :    0
Warnings :    0
```

NOTES:

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