Column #97 May 2003 by Jon Williams:

Keyboard Entry and Display

I'm sure you've heard, perhaps many time, that "Imitation is the sincerest form of flattery." I happen to agree with that assertion. What I've also found is that imitation is an excellent opportunity for self-education. Let me explain.

I've been very fortunate in my career to be asked to provide training for those interested in learning what I happen to know. For the last couple of years, I've been employed by Parallax and have had the opportunity to teach many people [mostly teachers] how to program and use BASIC Stamps. I am often asked what steps one can take to learn to program BASIC Stamps, and I generally list three things:

1. Study the available documentation and examples
2. Solve a problem; yours or someone else's
3. Attempt to duplicate an existing device

Of course, for the purposes of this month's article, we're going to focus on suggestion #3.

The reason, honestly, has to do with a recent training session I conducted in the city of Utrecht, located in western Holland, not too far from Amsterdam. At that meeting I met an engineer named Wolter who showed me a really interesting project that he is working on and needing some assistance with. The UI for the project consisted of a 4x4 matrix keyboard connected to the

BASIC Stamp through a 74C922. His demo used the DEBUG window but ultimately he would install an LCD for local display.

After returning to Texas I had a couple of idea exchanges with Wolter. His use of the 74C922 and wanting to use an LCD tickled my interest. I remembered seeing this combination, and finally found it by digging through my old documentation. Way back in the early days of the BASIC Stamp, my buddy Scott Edwards (the creator of this column) had designed such a project with the BS1, and very cleverly came up with a scheme that allowed the 74C922 and the LCD to share the same IO pins. This makes perfect sense from a resource conservation point-of-view, since the Stamp can't write to the LCD and read from the 74922 at the same time. So we're going to use Scott's hardware design with a BS2 and imitate a controller that I recently encountered.

Okay, what am I imitating? Well, not long ago I needed some extra storage space so, like many people, I went and rented a small room from on of those 24-hour-access storage companies. After signing the paperwork I was asked to give them a 4-digit access code of my choosing. The manager programmed the code into a computer then took me outside to the gate-access point to show me what to do with the code.

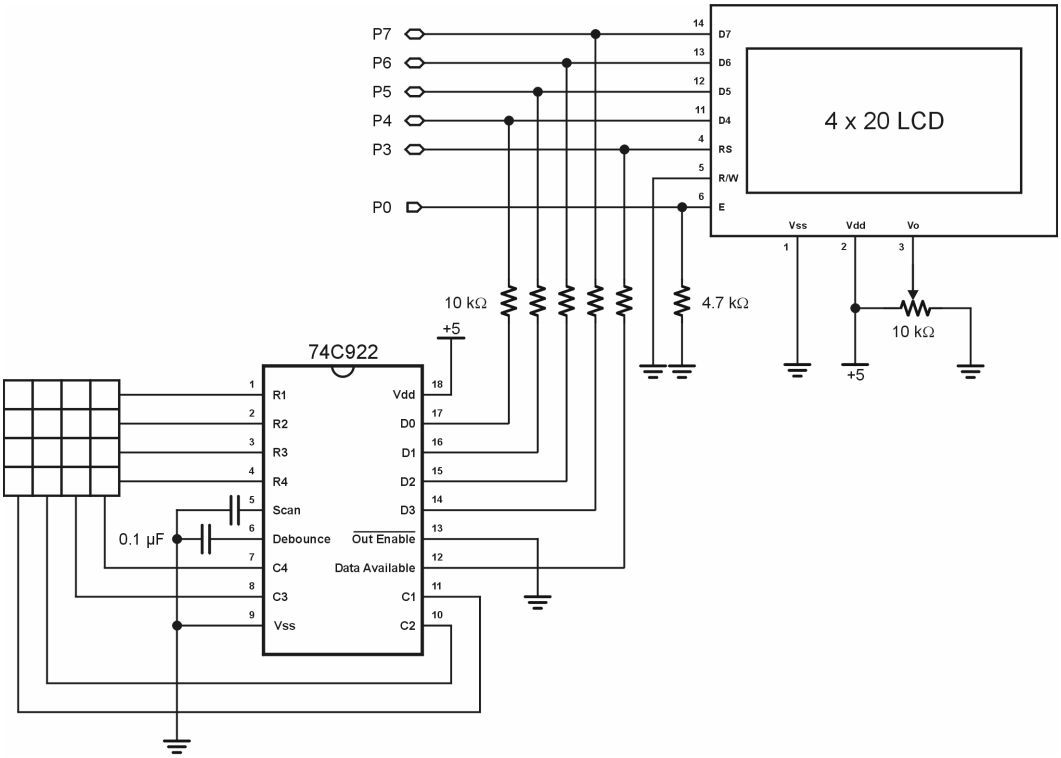
Just before the entry gate was a small box with a telephone-style keypad and an LCD display. The instructions were quite clear: Press the [*] key, enter your access code then press the [#] key. If the code was correct and my bill paid up, I would be welcomed to come on in and have access to my storage unit. The manager told me that if I ever had a problem with my bill, I'd get a small message to see her. I assured her there would be no problem – and, of course, there hasn't been.

After unloading some boxes into my nice new storage room, I found the same type control box on the exit of the facility. Getting out was the same as getting in and I had no problem. As I drove away I thought, "You know, I could have done that with a BASIC Stamp." So now I will.

Share and Share Alike

As I already mentioned, the hardware we'll use here was designed by Scott Edwards and is typical of his clever use of inexpensive components. Take a look at Figure 97.1. The outputs of the 74C922 are connected to the same pins used by the LCD buss and RS line through 10K resistors. The way the 74C922 works is very simple: When a key has been pressed, the Data Available pin goes high and the key value (0 – 15) is output from D0 – D3. When the Stamp pins are configured as inputs, the 10K resistors simply act like pull-ups and pull-downs so the pins can be read without any difficulty.

Figure 97.1: Keypad and LCD Interface



But won't we have a problem when we want to write to the LCD? Nope. Let's say that we want to send a high out to the LCD. If the associated 74C922 pin is also high then there is no issue (no current flow between Stamp and 74C922). If the 74C922 pin happens to be low, the high from the Stamp is felt across the 10K to the LCD. Again, no problem. Of course, the process is identical – just flipped – if we want to send a low to the LCD. That Scott Edwards is a very clever guy, isn't he?

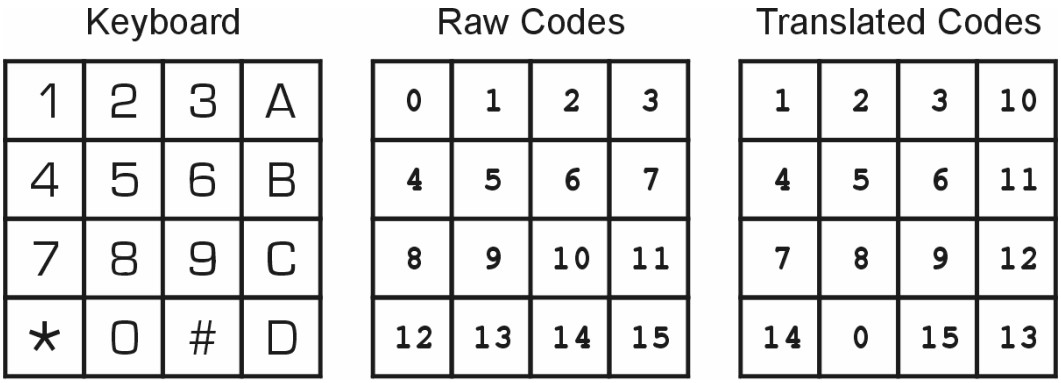
From a software standpoint there is no real challenge; we simply need to remember to make the buss pins inputs so we can read the 74C922 and make them outputs when we want to send data to the LCD. We can do that with just one line of code in each section.

Keyboard Input

After deciding to imitate the gate-entry controller I popped over to Tanner Electronics in Dallas and picked up a 74C922 and a Velleman 4x4 matrix keyboard. I put together a piece of test code and ran into my first problem to solve when using the keyboard and 74C922.

If you look at Figure 97.2 you'll see how the keyboard is laid out, how the raw values are returned and how I actually needed them to be (in order to match the keyboard). Thanks to the utility of the PBASIC programming language, the translation is easily handled with one line of code, though, as you'll see, I spread that single line across many to make it easier to read.

Figure 97.2: Keyboard, Raw Codes and Translated Codes



Let's go ahead and look at the code for reading a key. I made the decision that this subroutine would actually wait for a key before returning. Obviously, waiting doesn't work for all applications. In those cases where waiting is not possible, we'll simply check the Data Available (aliased as KeyReady) line externally before calling this code.

```
Get_Key:
  DirL = DirL & KeyCfg
  DO : LOOP UNTIL (KeyReady = Yes)
  keyIn = KeyPad

  LOOKUP keyIn, [  1,  2,  3, 10,
                   4,  5,  6, 11,
                   7,  8,  9, 12,
                  14,  0, 15, 13  ], keyIn

  LOOKUP keyIn, ["0123456789ABCD*#"], char
  IF (showNum AND (keyIn < 10)) THEN
```

```
  GOSUB Print_Char
ENDIF
IF (showExt AND (keyIn > 9)) THEN
  GOSUB Print Char
ENDIF
IF (release = Yes) THEN
  DO
    PAUSE 5
  LOOP WHILE (KeyReady = Yes)
ELSE
  PAUSE KeyDelay
ENDIF
RETURN
```

Before I get into a detailed explanation, let me just share some of my design decisions for this routine: it had to work with shared LCD lines, it had to translate the key code to match the printing on the keyboard, it had to translate the key to an ASCII character for display, it had to selectively allow display of digit and non-digit keys and finally, it had to create a delay for a key being held down or force the user to release the key before pressing it again.

Now that you know the design decision, the code will be even simpler to follow. We start by making the associated IO lines inputs so they can be read by the Stamp. The first to be checked, of course, is the Data Available output from the 74C922, which the program has aliased as KeyReady. As you can see, the program will wait for a key to be ready using a DO-LOOP. Once a key is detected, the raw key value is read from the keyboard buss.

Translating the raw key code to a value that matches the keyboard layout is a simple matter of using LOOKUP. One of the new features of the PBASIC compiler is the ability to break long list over multiple line (at the commas). We can take advantage of that feature with our translation code and even format the line so that the translation table exactly matches the keyboard. Once we have the translated key code, deriving the ASCII character for it is accomplished by using another LOOKUP table.

This subroutine uses control variables to determine the rest of its behavior. The first is a bit called showNum that when set to one (Yes), will allow the routine to print the ASCII value of the key characters "0" to "9". The next control variable is called showExt (show extended); its purpose is to allow the display of the characters beyond the numeric set. In the case of the keyboard I used in my project, it has four hex characters, a star and the pound sign (it's a telephone keypad with "A" – "D" added). Finally, the variable release controls key repeating. When release is set to one, the user must release the key before the next can be read. In this case there is a short delay loop built in to prevent accidental repeating. When release is set to zero, a PAUSE is used to create a repeat delay for the key being held.

As you can see, this is a very robust input routine; I designed it that way. Many applications will have simpler requirements and you can strip away those things not needed in those applications.

Numeric Input

A frequent question on the BASIC Stamps mailing list is "How can I enter a number using a keyboard." Since my little gate control application needs this, I have created a fairly full-featured routine to accept numeric input from the keyboard. It also allows the user to escape without making the entry. As with the Get_Key subroutine, the Get_Number subroutine uses control variables and even affects bit flags. Let's take a look at the code:

```
Get Number:
  number = 0
  inDigits = 0
  hasNum = No
  showNum = No
  showExt = No
  DO
    GOSUB Get Key
    IF (keyIn < 10) THEN
      IF (inDigits < maxDigits) THEN
        GOSUB Print_Char
        number = number * 10 + keyIn
        inDigits = inDigits + 1
        hasNum = Yes
      ENDIF
    ELSE
      IF (keyIn = StarKey) THEN
        hasNum = No
        EXIT
      ENDIF
    ENDIF
  LOOP UNTIL (keyIn = PoundKey)
  RETURN
```

The subroutine starts by clearing the return value (number), the number of digits entered (inDigits) and the flag indicating a valid entry (hasNum). It also clears the external display control variables, since the routine will want to examine the returned key before displaying it.

One of the control variables used is called maxDigits. This value will cause the routine to stop accepting value keys after a specified number of digits have been entered. Of course, the maximum digits that can be entered is five, but we must be careful entering numbers like 99999 will cause a rollover error since it's greater than the 16-bit maximum value of 65,536.

What the routine does, then, is wait for a key, check to see if it's a digit (0 – 9), then checks to see if there are digits left in our entry field. If this is the case, the character is printed and the key added to the return variable. A flag variable, hasNum, is set to indicate that we have in fact entered a number

To add the new key to our numeric value, what we need to do is a decimal left shift of the current value, and then add the new digit to the one's column. Doing the decimal left shift accomplished by multiplying the current numeric value by 10. This process moves the previously-entered digits to the left.

Once we've entered enough digits to fill the entry field, the routine will simply ignore any key except the star key which is used for escape, or the pound key which is used to accept the value. If the star key is pressed, you'll notice that the hasNum flag is cleared and the key input DO-LOOP is terminated with EXIT. Another way to end the entry loop is to press the pound key.

Advance Use of Conditional Compilation

Back in March I introduced you to another new Stamp compiler feature: conditional compilation. Most of the time I use this to set constants based on the connected Stamp, but we can also use it to determine code sections to compile based on our own settings.

Let's say, for example, that we didn't have a 4x20 LCD handy but wanted to get started on the code while we waited for the good folks at Digi-Key to ship out our order. The Stamp compiler has a display feature built in (the DEBUG window) … can we use it to prove our program while waiting on the display? Yes. Let me show you how.

Remember that conditional compilation control symbols are defined as either true (not zero) or false (zero). If the compiler encounters a symbol that has not been defined, it is assigned a value of false. I prefer to be very explicit in my declarations using zero and one. Like this:

```
#DEFINE __LCD = 1
```

I've made the decision to precede conditional compilation symbols with two underscore characters; this isn't a requirement, just the convention I've selected for myself. While I'm waiting for my LCD to arrive, I'll change the definition to this:

```
#DEFINE __LCD = 0
```

Note that we can't use the constants Yes (1) and No (0) in our conditional compilation symbol definitions because conditional compilation directives are evaluated before anything else in the program, including constants definitions.

If you look back in the Get_Key subroutine, you'll see a call to a subroutine called Print_Char. Here it is:

```
Print Char:
  #IF __LCD #THEN
    GOTO LCD_Write
  #ELSE
    DEBUG char
    RETURN
  #ENDIF
```

When the LCD is selected, the character (passed in char) to the LCD_Write subroutine. Also note that GOTO is used here since there a RETURN at the end of LCD_Write. What Print_Char becomes, in this case, is an entry to the subroutine LCD_Write. If the LCD is not selected then the DEBUG window is used. What this means is you can run the program with or without the LCD. Likewise, one could develop a program that used either a standard LCD or serial LCD.

One last note on conditional compilation: The directives actually control which lines of code are compiled and downloaded to the BASIC Stamp. Keep this is mind, since code compiled under one condition may need considerably more EEPROM space than under another. Remember that you can keep track of compiled code space with the Memory Map function in the editor.

With the grunt work out of the way, the rest of the gate-control code is fairly simple:

1. Display menu
2. Wait for code
3. Check code against known codes
4. Open gate if code is valid.

The program takes advantage of techniques we've used in the past, including last month's suggestion to store strings in EEPROM. This is, of course, is a demonstration program but could certainly be developed into a full-fledged application using past projects, including the serial interface for updating the customer database, and a real-time-clock to log entry and exit times.

Have fun with it, and Happy Stamping!

```
' =============================================================================
'
'   File...... Security_Gate.BS2
'   Purpose... Security gate entry controller and message display
'   Author.... Jon Williams, Parallax
'   E-mail.... jwilliams@parallax.com
'   Started...
'   Updated... 22 MAR 2003
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =============================================================================


' -----[ Program Description ]---------------------------------------------
'
' Provides entry control for a security gate or similar security system.
' The purpose of the program is to demonstrate keyboard input using the
' 74C922 and the conservation of Stamp IO resources by sharing buss lines
' with an LCD (hardware design by Scott Edwards).
'
' The (Velleman) keyboard used for this program is layed out like this:
'
'  --- --- --- ---
' | 1 | 2 | 3 | A |  R1
'  --- --- --- ---
' | 4 | 5 | 6 | B |  R2
'  --- --- --- ---
' | 7 | 8 | 9 | C |  R3
'  --- --- --- ---
' | * | 0 | # | D |  R4
'  --- --- --- ---
'
'   C   C   C   C
'   1   2   3   4


' -----[ Revision History ]------------------------------------------------


' -----[ I/O Definitions ]--------------------------------------------------

LcdE            PIN     0                       ' LCD Enable pin
LcdRs           PIN     3                       ' Register Select
LcdBuss         VAR     OUTB                    ' 4-bit LCD data bus

KeyReady        PIN     3                       ' high when key available
KeyPad          VAR     INB                     ' keys on pins 4 - 7
```

```
GateCtrl  PIN  15      ' use LED to indicate


' -----[ Conditional Compilation ]-------------------------------------

#DEFINE __LCD = 1        ' use LCD (otherwise DEBUG)


' -----[ Constants ]-----------------------------------------------------

Yes             CON     1                       ' input or output high
No              CON     0                       ' input or output low

KeyCfg          CON     %00000111               ' keyboard port config

KeyDelay        CON     250                     ' auto-repeat delay
StarKey         CON     14                      ' [*] key
PoundKey        CON     15                      ' [#] key

ClrLCD          CON     $01                     ' clear the LCD
CrsrHm          CON     $02                     ' move cursor to home
DDRam           CON     $80                     ' Display Data RAM control
CGRam           CON     $40                     ' Custom character RAM
Line0           CON     DDRam + 0               ' DDRAM address of line 1
Line1           CON     DDRam + 64              ' DDRAM address of line 2
Line2           CON     DDRam + 20              ' DDRAM address of line 3
Line3           CON     DDRam + 84              ' DDRAM address of line 4

LcdCfg          CON     %11111001               ' LCD port config

MsgPause        CON     1500                    ' delay for message display


' -----[ Variables ]-----------------------------------------------------

keyIn           VAR     Byte                    ' returned by Get_Key
showNum         VAR     Bit                     ' show number keys?
showExt         VAR     Bit                     ' show extended keys?
release         VAR     Bit                     ' force key release

number          VAR     Word                    ' returned by Get Number
hasNum          VAR     Bit                     ' was number accepted?
inDigits        VAR     Nib                     ' input digits
maxDigits       VAR     Nib                     ' max digits to enter

char            VAR    Byte                     ' ASCII char to display
eeAddr          VAR     Word                    ' address of char in EE

lineNum         VAR     Nib                     ' display line; 0 to 3
colNum          VAR     Byte                    ' column; 0 to 19
```

```
records         VAR     Byte                    ' number of user records
pcode           VAR     Word                    ' passcode from db
msgNum          VAR     Nib                     ' message to display
idx             VAR     Byte                    ' general purpose var


' -----[ EEPROM Data ]----------------------------------------------------

Menu1           DATA    "JONNY'S STORAGE", 0
Menu2           DATA    "1. Press *", 0
Menu3           DATA    "2. Enter passcode", 0
Menu4           DATA    "3. Press #", 0

EnterPC         DATA    "Passcode: ", 0
WaitPlease      DATA    "Please wait...      ", 0

Msg0            DATA    "Invalid passcode    ", 0
Msg1            DATA    "Access granted      ", 0
Msg2            DATA    "Access denied       ", 0
Msg3            DATA    "Please see manager  ", 0

' Keep customer database after messages to allow for growth
' via external serial interface (not included here)
'
' Each record consists of the passcode and display message pointer

Customers       DATA    3                       ' number of customers
Passcodes       DATA    Word 1234, 1            ' customer passcodes, msgs
                DATA    Word 0725, 1
                DATA    Word 0319, 2


' -----[ Initialization ]-------------------------------------------------

Initialize:
#IF __LCD #THEN
  PAUSE 500                                     ' let the LCD settle
  DirL = LcdCfg
  LcdBuss = %0011               ' 8-bit mode
  PULSOUT LcdE, 1 : PAUSE 5
  PULSOUT LcdE, 1 : PAUSE 0
  PULSOUT LcdE, 1 : PAUSE 0
  LcdBuss = %0010                               ' 4-bit mode
  PULSOUT LcdE, 1
  char = %00101000                              ' 2-line mode
  GOSUB LCD Command
  char = %00001100                              ' no crsr, no blink
  GOSUB LCD_Command
  char = %00000110                              ' inc crsr, no disp shift
  GOSUB LCD Command
#ENDIF
```

```
' -----[ Program Code ]----------------------------------------------------

Main:
  DO
    GOSUB Show_Menu
    DO
      GOSUB Get Key
    LOOP UNTIL (keyIn = StarKey)                ' wait for [*]
    GOSUB Get Passcode                          ' get code from customer
    IF (hasNum = Yes) THEN                      ' code entered?
      GOSUB Check_Passcode                      ' check database
      GOSUB Print Customer Message              ' print message
      PAUSE MsgPause                            ' time for message
      IF (msgNum = 1) THEN                      ' valid code?
        GOSUB Access Granded
      ELSE
        IF (msgNum = 2) THEN                    ' two-part message?
          msgNum = 3
          GOSUB Print Customer Message          ' print second part
          PAUSE MsgPause
        ENDIF
      ENDIF
    ENDIF
  LOOP

  END


' -----[ Subroutines ]------------------------------------------------------

' Display menu strings stored in DATA table

Show Menu:
  GOSUB Clear_Display
  colNum = 0
  FOR lineNum = 0 TO 3
    LOOKUP lineNum, [Menu1, Menu2, Menu3, Menu4], eeAddr
    GOSUB Move To XY
    GOSUB Print String
  NEXT
  RETURN


' Get passcode from customer -- user numeric input

Get_Passcode:
  GOSUB Clear_Display
  eeAddr = Menu1                                ' reprint company name
  GOSUB Print_String
```

```
  lineNum = 3 : colNum = 0
  GOSUB Move To XY
  eeAddr = EnterPC                              ' print entry prompt
  GOSUB Print String
  maxDigits = 4
  GOSUB Get_Number                              ' enter passcode
  RETURN


' Compare user-entered passcode against database

Check_Passcode:                                 ' check for valid pc
  lineNum = 3 : colNum = 0                      ' wait msg on line 3
  GOSUB Move To XY
  eeAddr = WaitPlease
  GOSUB Print String
  msgNum = 0                                    ' default to "Invalid"
  READ Customers, records                       ' get number of customers
  FOR idx = 0 TO (records - 1)                  ' loop through all
    eeAddr = Passcodes + (3 * idx)              ' point to passcode
    READ eeAddr, Word pCode                     ' read it
    IF (number = pCode) THEN                    ' same as entry?
      eeAddr = eeAddr + 2                       ' - point to message num
      READ eeAddr, msgNum                       ' - read message num
      EXIT                                      ' - break out of loop
    ENDIF
  NEXT
  RETURN


' Print message in msgNum on Line 3

Print Customer Message:
  lineNum = 3 : colNum = 0
  GOSUB Move To XY
  LOOKUP msgNum, [Msg0, Msg1, Msg2, Msg3], eeAddr
  GOSUB Print_String
  RETURN


' Allow access to facility

Access_Granded:
  HIGH GateCtrl                                 ' - raise gate
  PAUSE 2500
  LOW GateCtrl
  RETURN


' Wait for key to be pressed, then return its value to caller
' -- can translate and display ASCII char of key
```

```
' -- can force user to release or use timed debounce

Get Key:
  DirL = DirL & KeyCfg         ' configure for kbd inputs
  DO : LOOP UNTIL (KeyReady = Yes)              ' wait for key
  keyIn = KeyPad                                ' retrieve key value

  LOOKUP keyIn, [  1,  2,  3, 10,
                   4,  5,  6, 11,
                   7,  8,  9, 12,
                  14,  0, 15, 13  ], keyIn      ' translate kbd matrix

  LOOKUP keyIn, ["0123456789ABCD*#"], char      ' translate key to ASCII
  IF (showNum AND (keyIn < 10)) THEN            ' show numbers?
    GOSUB Print Char
  ENDIF
  IF (showExt AND (keyIn > 9)) THEN             ' show extended chars?
    GOSUB Print_Char
  ENDIF
  IF (release = Yes) THEN                       ' force release?
    DO
      PAUSE 5                                   ' short debounce
    LOOP WHILE (KeyReady = Yes)                 ' wait for release
  ELSE
    PAUSE KeyDelay                              ' delay between keys
  ENDIF
  RETURN


' Get a number of 1 to 5 digits
' -- character display is handled here
' -- [*] terminates input without accepting value
' -- [#] terminates input and accepts value
'
' NOTE: No error checking for 5-digit numbers greater than 65535

Get_Number:
  number = 0                                    ' clear work variable
  inDigits = 0                                  ' digits entered
  hasNum = No                                   ' nothing entered yet
  showNum = No                                  ' control display here
  showExt = No
  DO
    GOSUB Get Key                               ' wait for new key
    IF (keyIn < 10) THEN                        ' number key?
      IF (inDigits < maxDigits) THEN            ' room for entry?
        GOSUB Print Char                        ' - show the key
        number = number * 10 + keyIn            ' - add key to number
        inDigits = inDigits + 1                 ' - update digit count
        hasNum = Yes                            ' - mark entry
      ENDIF
```

```
    ELSE
      IF (keyIn = StarKey) THEN                ' [*] = escape
        hasNum = No
        EXIT
      ENDIF
    ENDIF
  LOOP UNTIL (keyIn = PoundKey)                ' wait for [#]
  RETURN


' Print string on display device at current position
' -- point to string by placing address in eeAddr

Print String:
  DO
    READ eeAddr, char                          ' get character from EE
    IF (char = 0) THEN EXIT                    ' check end
    GOSUB Print_Char                           ' print it
    eeAddr = eeAddr + 1                        ' point to next
  LOOP
  RETURN


' Print character in char at current display position

Print Char:
  #IF   LCD #THEN
    GOTO LCD Write
  #ELSE
    DEBUG char
    RETURN
  #ENDIF


' Clear the display (moves cursor Home)

Clear_Display:
  #IF   LCD #THEN
    char = ClrLCD
    GOTO LCD Command
  #ELSE
    DEBUG CLS
    RETURN
  #ENDIF


' Move display cursor to column 0 on line 0

Home_Cursor:
  #IF   LCD #THEN
    char = CrsrHm
```

```
    GOTO LCD_Command
  #ELSE
    DEBUG Home
    RETURN
  #ENDIF


' Move display cursor to lineNum, colNum

Move To XY:
  #IF   LCD #THEN
    LOOKUP lineNum, [Line0, Line1, Line2, Line3], char
    char = char + (colNum // 20)
    GOTO LCD Command
  #ELSE
    DEBUG CrsrXY, colNum, lineNum
    RETURN
  #ENDIF


' LCD output routines

#IF   LCD #THEN

LCD_Command:
  LOW LcdRs                                     ' enter command mode

LCD Write:
  DirL = DirL | LcdCfg                          ' make LCD buss outputs
  LcdBuss = char.HighNib                        ' output high nibble
  PULSOUT LcdE, 1                               ' strobe the Enable line
  LcdBuss = char.LowNib                         ' output low nibble
  PULSOUT LcdE, 1
  HIGH LcdRs                                    ' back to character mode
  RETURN

#ENDIF
```