Column #99 July 2003 by Jon Williams:

You've Got Robot Eyes

How about something simple this month, yet useful and even fun. Good – I've had a crazy couple of weeks leading up to writing this, especially the last few days. Today I told my best friend Farah, that the only thing stopping me from throwing myself from the balcony is the thought that falling just three stories would only add painful injury to the string of insults [uncooperative projects] I've been dealing with for the past several days.... Zoiks.

Now, things haven't been all bad. The other day I received a package from my friends in Holland (I conducted some BASIC and Javelin Stamp training sessions there in February). Amongst the goodies were some great books ... and books are just about my favorite thing in the whole wide world next to BASIC Stamps. The book that I've really been enjoying while on my reading breaks is "The I2C Bus" (ISBN 0-905705-47-5) that is published by Elektor Electronics magazine. If you've not seen Elektor, it is to Europe what Nuts & Volts is to the United States: a high-quality electronics magazine that targets serious hobbyists like you and me.

Thumbing through the various I2C projects in the book encouraged me to spruce up my BASIC Stamp I2C library (for non-BS2p/pe Stamps) to take advantage of PBASIC 2.5, to put aside my various uncooperative projects, and to try the Devantech SRF08 ultrasonic range finder that's been begging me for some attention.

The SRF08 is physically identical to the SRF04 we experimented with last year, but it's two-wire connection is an I2C bus instead of a trigger input and pulse output. The advantage for us is that we can connect up to 16 SRF08s on the same two wires. This is perfect for an array of robot "eyes."

Let's get right to it. Figure 99.1 shows the connections that will work with our BS2/BS2e/BS2sx I2C routines, as well as I2COUT an I2CIN on the BS2p and BS2pe.

Figure 99.1: SRF08 to BASIC Stamp Connection

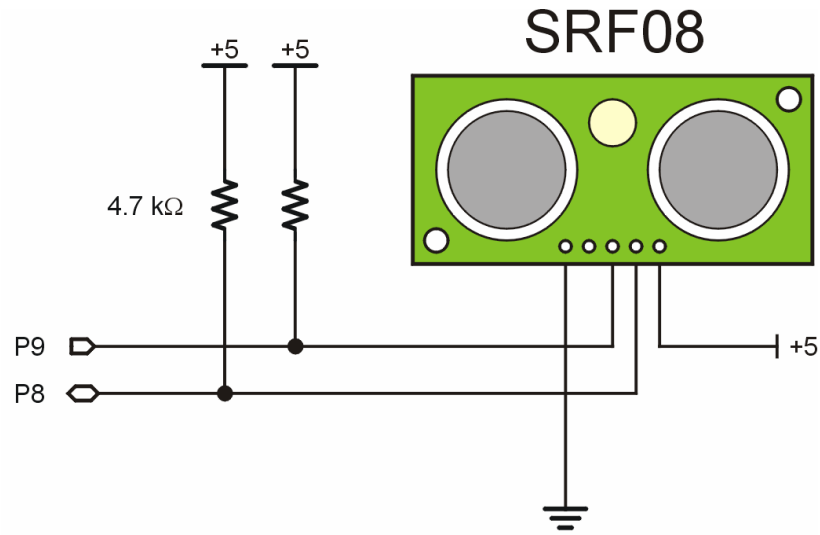
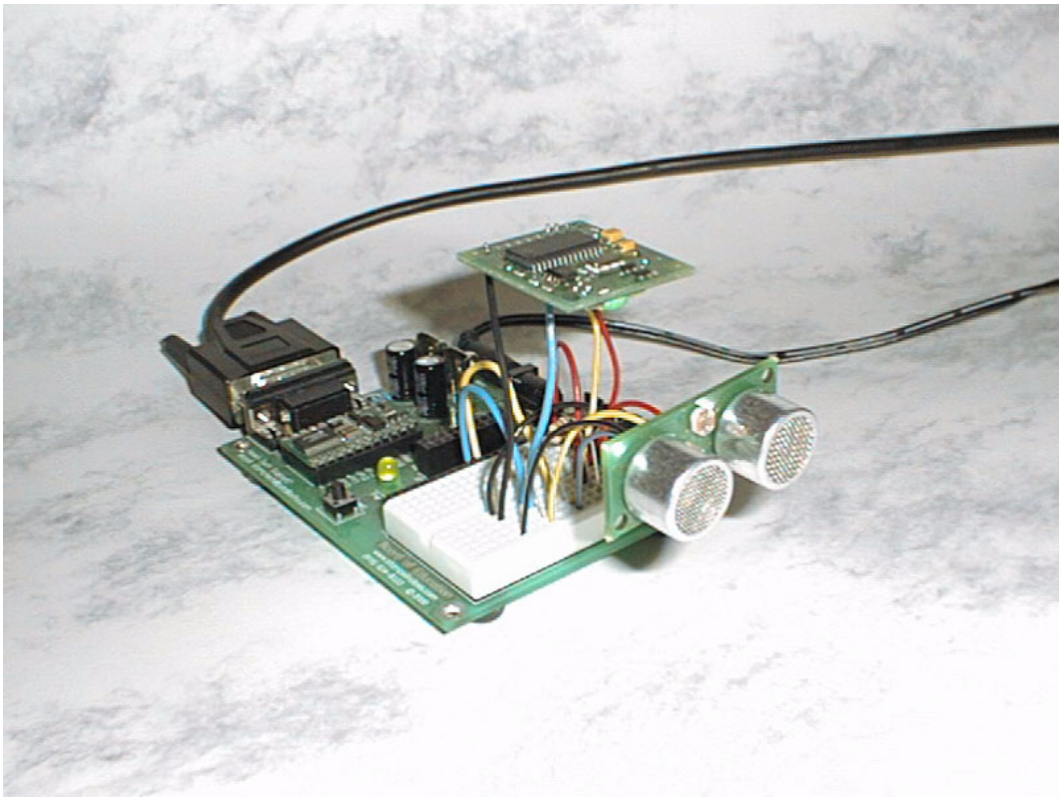


Figure 99.2: SRF08 to BASIC Stamp



What's Your Address?

Since we discussed I2C bus details last year, I won't go into that accept to remind you that I2C devices have a slave address (device code) and internal register addresses. Most I2C devices have external address pins that allow us to set the device address (a few devices have fixed addresses – like the CMPS01 from Devantech). With the SRF08 we must set its address electronically; through the I2C bus.

If we have only SRF08 in a project, we can use the default address, $E0, and deal with the range finder much like an I2C EEPROM. To use more than one on the same bus, of course, necessitates an address change in one or more units. This is actually very simple to do. What is required is the

transmission of a specific byte sequence ($A0, $AA, $A5) to the command register ($00), followed by the new address (there are 16 valid choices). Here's the code:

```
FOR idx = 0 TO 3
  i2cSlave = $00
  i2cReg = RegCmd
  LOOKUP idx, [$A0, $AA, $A5, NewSRF08], i2cData
  GOSUB Write Byte
NEXT
```

The slave address used by this routine is the "broadcast" address ($00) that will act on any SRF08 (more on this later). Once the address is set, it's a good idea to give the use a method of verification. Luckily, the SRF08 has an onboard LED that blinks when its slave address is received. We can cause this LED to blink by putting the code into a loop that writes a valid command to the SRF08 command register.

```
DO
  i2cSlave = NewSRF08
  i2cReg = RegCmd
  i2cData = $50
  GOSUB Write Byte
  PAUSE 65
LOOP
```

When power is cycled on the SRF08, the LED will display a code of long and short blinks that indicates the slave address setting. It is a good idea, however, to mark the device after we've changed the address – this will make things easier later.

How Far to the Next Obstacle?

With the device address set, reading the distance from the sensor to an obstacle is a simple process:

- Send a ranging command to the desired device
- Wait 65 milliseconds for the measurement
- Read the range

The first step is to send a ranging command. In addition to the ability to control multiple devices on the same bus, I really like this feature: we can specify range in inches, centimeters, or in microseconds. This saves us conversion math in PBASIC. To start the process, the ranging command ($50 for inches, $51 for centimeters, $52 for microseconds) is written to the command register at [internal] address $00. After 65 milliseconds, the ranging value is ready and we read the two-byte range value from registers $02 and $03.

If you look closely at the SRF08 you'll see a CdS photocell nestled neatly between the ultrasonic elements. This is another nice feature of the SRF08: each time a range measurement is made, the light falling on the photocell is measured and placed in register $01. This will be an eight-bit value that will get larger as more light falls on the photocell.

Since the program is fairly short, we can print most of it [sans I2C routines] here. This setup code takes care of formatting our DEBUG terminal screen and displaying the revision code of the SRF08. The revision code is read from register $00 (same address where we write the command value).

```
Setup:
  DEBUG CLS
  DEBUG CrsrXY, 0, 0, "Devantech SRF08 Range Finder Demo"
  DEBUG CrsrXY, 0, 1, "--------------------------------"

  i2cSlave = SRF08
  i2cReg = RegCmd
  GOSUB Read Byte
  DEBUG CrsrXY, 0, 3, "Rev Num... "
  DEBUG DEC i2cData, ClrEOL

  DEBUG CrsrXY, 0, 5, "Light..... "
  DEBUG CrsrXY, 0, 6, "Range..... "
```

The main code sends the ranging command (inches), gives the SRF08 the time it needs to make the measurement, then reads back and displays the light and measurement values. The guys at Devantech have made the SRF08 a breeze to use.

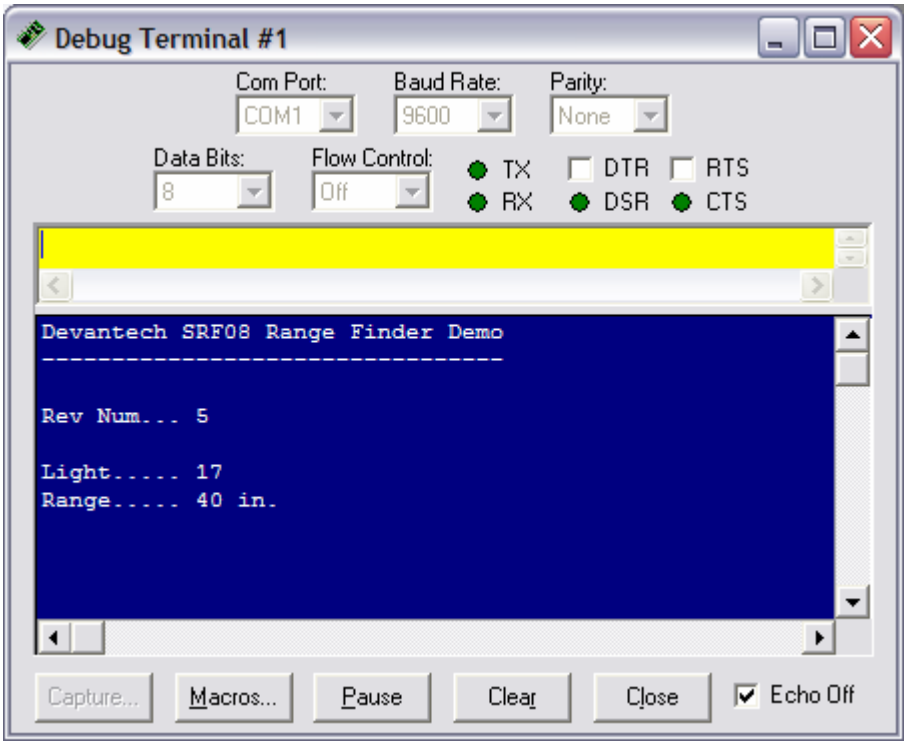
```
Main:
  i2cSlave = SRF08
  i2cReg = RegCmd
  i2cData = RngIn
  GOSUB Write Byte
  PAUSE 65
  i2cReg = RegLight
  GOSUB Read_Byte
  DEBUG CrsrXY, 11, 5, DEC i2cData, ClrEOL
  i2cReg = RegRange
  GOSUB Read Word
  DEBUG CrsrXY, 11, 6, DEC i2cData, " in.", ClrEOL
  GOTO Main
```

Now, what if we want to talk to more than one SRF08? Do we need to address them and wait for each one? No. Remember I mentioned the "broadcast" command earlier? All we have to do is

send a ranging command to the broadcast address ($00), wait 65 milliseconds, then loop through each of our sensors and read its range value.

```
Read_Sensors:
  i2cSlave = $00
  i2cReg = RegCmd
  i2cData = RngIn
  GOSUB Write Byte
  PAUSE 65
  FOR idx = 0 TO 2
    LOOKUP idx, [$E0, $E2, $E4], i2cSlave
    i2cReg = RegRange
    GOSUB Read Word
    sonar(idx) = i2cData
  NEXT
```

Figure 99.3: Example DEBUG Output



Remote Robot Start With a Laser

Many of the contests conducted by the Dallas Personal Robotics Group give a few extra points to robots that can be started without touching them. At a contest some months back, DPRG member David Anderson (a great robot builder and programmer) asked me if I had a laser pointer with me. As it happened, I did have one in my toolbox. He smiled, pointed it at his robot, and away it went – extra points scored.

Remember a couple months ago when I talked about learning through imitating? Well, that's what I did with David's laser trick. Since the SRF08 is a great robot part, and it has a CdS photocell, I wrote a short piece of code that lets us handle "non-contact" starts.

The concept is simple: read the ambient light on start-up, then wait until there is a significant rise in the light level. This rise, of course, will be caused by the laser pointer hitting the CdS. In my code, I decided a 25% change is significant. You may need to adjust for the ambient lighting in your situation. A smaller percentage change will make the trigger more sensitive. Be careful though, as too small a change could make the remote start subject to false triggering.

Here's the code that reads the ambient light and establishes the start threshold of 125%:

```
Setup:
  i2cSlave = SRF08
  i2cReg = RegCmd
  i2cData = RngIn
  GOSUB Write_Byte
  PAUSE 65
  i2cReg = RegLight
  GOSUB Read Byte
  thresh = i2cData.LowByte */ $0140 MAX 255
```

The next step, then, is to monitor the light level until the threshold is exceeded.

Wait_For_Start:

```
  DO
    i2cSlave = SRF08
    i2cReg = RegCmd
    i2cData = RngIn
    GOSUB Write_Byte
    PAUSE 65
    i2cReg = RegLight
    GOSUB Read Byte
  LOOP UNTIL (i2cData >= thresh)
```

See? I told you this was going to be easy. It's really a credit to Devantech and the work they put into the SRF08. And bear in mind that the SRF08 is capable of more than we've covered here – but these are the features that are most useful. The documentation and Devantech web site cover advanced features like multiple echoes.

For fun I've included a photo of my test BOE with an SRF08 and CMPS01 – just to make sure they "play nice." Of course they do. Now I just need to strap it onto a BOE-Bot chassis and let it tear around my apartment. After I do that I think I'll attach a big laser and target some of those uncooperative projects that have been troubling me for the past several days. I'll let you know how that goes.

Until next time, Happy Stamping.

```
' =============================================================================
'
'   File...... SRF08_Demo.BS2
'   Purpose... Daventech SRF08 Ultrasonic Range Finder Demonstration
'   Author.... Jon Williams
'   E-mail.... jwilliams@parallax.com
'   Started...
'   Updated... 20 MAY 2003
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =============================================================================


' -----[ Program Description ]---------------------------------------------


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


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

SDA             PIN     8                       ' I2C serial data line
SCL             PIN     9                       ' I2C serial clock line


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

SRF08           CON     $E2                     ' address of SRF08

RegCmd          CON     0                       ' command register
RegLight        CON     1                       ' light value
RegRange        CON     2                       ' ranger reading

RngIn           CON     $50                     ' range in inches
RngCm           CON     $51                     ' range in centimeters
RngUs           CON     $52                     ' range in microseconds

Ack             CON     0                       ' acknowledge bit
Nak             CON     1                       ' no ack bit


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

i2cSlave        VAR     Byte                    ' I2C device address
i2cReg          VAR     Byte                    ' register address
i2cData         VAR     Word                    ' data to/from device
i2cWork         VAR     Byte                    ' work byte for I2C io
i2cAck          VAR     Bit                     ' Ack bit from device
```

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


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

Setup:
  DEBUG CLS
  DEBUG CRSRXY, 0, 0, "Devantech SRF08 Range Finder Demo"
  DEBUG CRSRXY, 0, 1, "--------------------------------"

  i2cSlave = SRF08                              ' set device ID
  i2cReg = RegCmd                               ' rev number in cmd reg
  GOSUB Read Byte
  DEBUG CRSRXY, 0, 3, "Rev Num... "
  DEBUG DEC i2cData, CLREOL

  DEBUG CRSRXY, 0, 5, "Light..... "
  DEBUG CRSRXY, 0, 6, "Range..... "


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

Main:
  i2cSlave = SRF08
  i2cReg = RegCmd
  i2cData = RngIn                               ' get range in inches
  GOSUB Write Byte
  PAUSE 65                                      ' allow measurement
  i2cReg = RegLight
  GOSUB Read Byte
  DEBUG CRSRXY, 11, 5, DEC i2cData, CLREOL
  i2cReg = RegRange
  GOSUB Read Word
  DEBUG CRSRXY, 11, 6, DEC i2cData, " in.", CLREOL
  GOTO Main

  END



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

' --------------------------
' High Level I2C Subroutines
' --------------------------

' Writes low byte of i2cData to i2cReg

Write_Byte:
```

```
  GOSUB I2C_Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                          ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                          ' send register number
  i2cWork = i2cData.LowByte
  GOSUB I2C_TX_Byte                          ' send the data
  GOSUB I2C Stop
  RETURN


' Writes i2cData to i2cReg

Write Word:
  GOSUB I2C Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                          ' send device address
  i2cWork = i2cReg
  GOSUB I2C_TX_Byte                          ' send register number
  i2cWork = i2cData.HighByte
  GOSUB I2C TX Byte                          ' send the data - high byte
  i2cWork = i2cData.LowByte
  GOSUB I2C TX Byte                          ' send the data - low byte
  GOSUB I2C_Stop
  RETURN


' Read i2cData (8 bits) from i2cReg

Read_Byte:
  GOSUB I2C_Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                          ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                          ' send register number
  GOSUB I2C_Start                            ' start (sets register)
  i2cWork = (i2cSlave | 1)
  GOSUB I2C TX Byte                          ' send read command
  GOSUB I2C RX Byte Nak
  GOSUB I2C Stop
  i2cData = i2cWork                          ' return the data
  RETURN


' Read i2cData (16 bits) from i2cReg

Read Word:
  GOSUB I2C_Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                          ' send device address
  i2cWork = i2cReg
```

```
  GOSUB I2C_TX_Byte                             ' send register number
  GOSUB I2C Start                               ' start (sets register)
  i2cWork = (i2cSlave | 1)
  GOSUB I2C TX Byte                             ' send read command
  GOSUB I2C RX Byte
  i2cData.HighByte = i2cWork                    ' read high byte of data
  GOSUB I2C_RX_Byte_Nak
  GOSUB I2C Stop
  i2cData.LowByte = i2cWork                     ' read low byte of data
  RETURN


' -------------------------
' Low Level I2C Subroutines
' -------------------------

' --- Start ---

I2C_Start:                                      ' I2C start bit sequence
  INPUT SDA
  INPUT SCL
  LOW SDA                                       ' SDA --> low while SCL high

Clock_Hold:
  DO : LOOP WHILE (SCL = 0)                     ' wait for device ready
  RETURN


' --- Transmit ---

I2C_TX_Byte:
  SHIFTOUT SDA, SCL, MSBFIRST, [i2cWork\8]      ' send byte to device
  SHIFTIN SDA, SCL, MSBPRE, [i2cAck\1]          ' get acknowledge bit
  RETURN


' --- Receive ---

I2C RX Byte Nak:
  i2cAck = Nak                                  ' no Ack = high
  GOTO I2C RX

I2C_RX_Byte:
  i2cAck = Ack                                  ' Ack = low

I2C RX:
  SHIFTIN SDA, SCL, MSBPRE, [i2cWork\8]         ' get byte from device
  SHIFTOUT SDA, SCL, LSBFIRST, [i2cAck\1]       ' send ack or nak
  RETURN
```

```
' --- Stop ---

I2C Stop:                                       ' I2C stop bit sequence
  LOW SDA
  INPUT SCL
  INPUT SDA                                     ' SDA --> high while SCL high
  RETURN
```

```
' ================================================================================
'
'   File...... SRF08 Laser Start.BS2
'   Purpose... Using the SRF08 Light Sensor for Robot Remote Start
'   Author.... Jon Williams
'   E-mail.... jwilliams@parallax.com
'   Started...
'   Updated... 20 MAY 2003
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' ================================================================================


' -----[ Program Description ]---------------------------------------------

' Monitors the light sensor for a distinct change -- can be used as a
' "non-contact" start for a robot.


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


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

SDA             PIN     8                       ' I2C serial data line
SCL             PIN     9                       ' I2C serial clock line


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

SRF08           CON     $E2                     ' address of SRF08

RegCmd          CON     0                       ' command register
RegLight        CON     1                       ' light value
RegRange        CON     2                       ' ranger reading

RngIn           CON     $50                     ' range in inches
RngCm           CON     $51                     ' range in centimeters
RngUs           CON     $52                     ' range in microseconds

Ack             CON     0                       ' acknowledge bit
Nak             CON     1                       ' no ack bit


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

i2cSlave        VAR     Byte                    ' I2C device address
i2cReg          VAR     Byte                    ' register address
i2cData         VAR     Word                    ' data to/from device
```

```
i2cWork         VAR     Byte                    ' work byte for I2C io
i2cAck          VAR     Bit                     ' Ack bit from device

thresh          VAR     Byte


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


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

Setup:
  i2cSlave = SRF08
  i2cReg = RegCmd
  i2cData = RngIn                               ' send range command
  GOSUB Write Byte
  PAUSE 65                                      ' allow measurement
  i2cReg = RegLight
  GOSUB Read_Byte
  thresh = i2cData.LOWBYTE */ $0140 MAX 255     ' thresh = ambient * 1.25

  DEBUG CLS
  DEBUG "Threshold set.  Waiting for start."


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

Wait For Start:
  DO
    i2cSlave = SRF08
    i2cReg = RegCmd
    i2cData = RngIn                             ' send range command
    GOSUB Write Byte
    PAUSE 65                                    ' allow measurement
    i2cReg = RegLight
    GOSUB Read_Byte
  LOOP UNTIL (i2cData >= thresh)

Main:
  DEBUG CR
  DEBUG "Start detected."

  END


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

' --------------------------
' High Level I2C Subroutines
' --------------------------
```

```
' Writes low byte of i2cData to i2cReg

Write Byte:
  GOSUB I2C Start
  i2cWork = i2cSlave
  GOSUB I2C_TX_Byte                          ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                          ' send register number
  i2cWork = i2cData.LOWBYTE
  GOSUB I2C TX Byte                          ' send the data
  GOSUB I2C Stop
  RETURN


' Writes i2cData to i2cReg

Write Word:
  GOSUB I2C_Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                          ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                          ' send register number
  i2cWork = i2cData.HIGHBYTE
  GOSUB I2C_TX_Byte                          ' send the data - high byte
  i2cWork = i2cData.LOWBYTE
  GOSUB I2C TX Byte                          ' send the data - low byte
  GOSUB I2C Stop
  RETURN


' Read i2cData (8 bits) from i2cReg

Read Byte:
  GOSUB I2C Start
  i2cWork = i2cSlave
  GOSUB I2C_TX_Byte                          ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                          ' send register number
  GOSUB I2C Start                            ' start (sets register)
  i2cWork = (i2cSlave | 1)
  GOSUB I2C TX Byte                          ' send read command
  GOSUB I2C_RX_Byte_Nak
  GOSUB I2C_Stop
  i2cData = i2cWork                          ' return the data
  RETURN


' Read i2cData (16 bits) from i2cReg

Read Word:
  GOSUB I2C_Start
```

```
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                             ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                             ' send register number
  GOSUB I2C Start                               ' start (sets register)
  i2cWork = (i2cSlave | 1)
  GOSUB I2C_TX_Byte                             ' send read command
  GOSUB I2C RX Byte
  i2cData.HighByte = i2cWork                    ' read high byte of data
  GOSUB I2C RX Byte Nak
  GOSUB I2C Stop
  i2cData.LowByte = i2cWork                     ' read low byte of data
  RETURN


' -------------------------
' Low Level I2C Subroutines
' -------------------------

' --- Start ---

I2C Start:                                      ' I2C start bit sequence
  INPUT SDA
  INPUT SCL
  LOW SDA                                       ' SDA --> low while SCL high

Clock Hold:
  DO : LOOP WHILE (SCL = 0)                     ' wait for device ready
  RETURN


' --- Transmit ---

I2C TX Byte:
  SHIFTOUT SDA, SCL, MSBFIRST, [i2cWork\8]      ' send byte to device
  SHIFTIN SDA, SCL, MSBPRE, [i2cAck\1]          ' get acknowledge bit
  RETURN


' --- Receive ---

I2C_RX_Byte_Nak:
  i2cAck = Nak                                  ' no Ack = high
  GOTO I2C RX

I2C RX Byte:
  i2cAck = Ack                                  ' Ack = low

I2C_RX:
  SHIFTIN SDA, SCL, MSBPRE, [i2cWork\8]         ' get byte from device
  SHIFTOUT SDA, SCL, LSBFIRST, [i2cAck\1]       ' send ack or nak
```

```
  RETURN


' --- Stop ---

I2C_Stop:                                       ' I2C stop bit sequence
  LOW SDA
  INPUT SCL
  INPUT SDA                                     ' SDA --> high while SCL high
  RETURN
```

```
' =============================================================================
'
'   File...... SRF08 Addr Set.BS2
'   Purpose... Daventech SRF08 Ultrasonic Range Finder Address Change
'   Author.... Jon Williams
'   E-mail.... jwilliams@parallax.com
'   Started...
'   Updated... 20 MAY 2003
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =============================================================================


' -----[ Program Description ]---------------------------------------------

' Use this program to set new address in SRF08.  To simplify the process,
' this routine uses the broadcast address, so make sure that only one
' device is connected.
'
' Valid Addresses:
'   $E0, $E2, $E4, $E6, $E8, $EA, $EC, $EE
'   $F0, $F2, $F4, $F6, $F8, $FA, $FC, $FE


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


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

SDA             PIN     8                       ' I2C serial data line
SCL             PIN     9                       ' I2C serial clock line


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

NewSRF08        CON     $E2                     ' new address for SRF08

RegCmd          CON     0                       ' command register
RegLight        CON     1                       ' light value
RegRange        CON     2                       ' ranger reading

Ack             CON     0                       ' acknowledge bit
Nak             CON     1                       ' no ack bit


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

i2cSlave        VAR     Byte                    ' I2C device address
i2cReg          VAR     Byte                    ' register address
```

```
i2cData         VAR     Word                    ' data to/from device
i2cWork         VAR     Byte                    ' work byte for I2C io
i2cAck          VAR     Bit                     ' Ack bit from device

idx             VAR     Nib                     ' loop counter


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


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


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

Main:
  DEBUG CLS
  DEBUG "Changing SRF08 address to: ", IHEX2 NewSRF08, CR
  DEBUG "Blinking LED confirms address change."

  FOR idx = 0 TO 3                              ' send byte sequence
    i2cSlave = $00
    i2cReg = RegCmd
    LOOKUP idx, [$A0, $AA, $A5, NewSRF08], i2cData
    GOSUB Write_Byte
  NEXT

  DO                                            ' blink LED to confirm
    i2cSlave = NewSRF08                         ' address
    i2cReg = RegCmd                             ' command register
    i2cData = $50                               ' range command
    GOSUB Write Byte                            ' send it
    PAUSE 65
  LOOP


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

' --------------------------
' High Level I2C Subroutines
' --------------------------

' Writes low byte of i2cData to i2cReg

Write Byte:
  GOSUB I2C Start
  i2cWork = i2cSlave
  GOSUB I2C_TX_Byte                             ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                             ' send register number
  i2cWork = i2cData.LowByte
```

```
  GOSUB I2C_TX_Byte                           ' send the data
  GOSUB I2C Stop
  RETURN


' Writes i2cData to i2cReg

Write Word:
  GOSUB I2C Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                           ' send device address
  i2cWork = i2cReg
  GOSUB I2C_TX_Byte                           ' send register number
  i2cWork = i2cData.HighByte
  GOSUB I2C TX Byte                           ' send the data - high byte
  i2cWork = i2cData.LowByte
  GOSUB I2C TX Byte                           ' send the data - low byte
  GOSUB I2C_Stop
  RETURN


' Read i2cData (8 bits) from i2cReg

Read_Byte:
  GOSUB I2C_Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                           ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                           ' send register number
  GOSUB I2C_Start                             ' start (sets register)
  i2cWork = (i2cSlave | 1)
  GOSUB I2C TX Byte                           ' send read command
  GOSUB I2C RX Byte Nak
  GOSUB I2C Stop
  i2cData = i2cWork                           ' return the data
  RETURN


' Read i2cData (16 bits) from i2cReg

Read Word:
  GOSUB I2C_Start
  i2cWork = i2cSlave
  GOSUB I2C TX Byte                           ' send device address
  i2cWork = i2cReg
  GOSUB I2C TX Byte                           ' send register number
  GOSUB I2C Start                             ' start (sets register)
  i2cWork = (i2cSlave | 1)
  GOSUB I2C_TX_Byte                           ' send read command
  GOSUB I2C RX Byte
  i2cData.HighByte = i2cWork                  ' read high byte of data
```

```
  GOSUB I2C_RX_Byte_Nak
  GOSUB I2C Stop
  i2cData.LowByte = i2cWork                     ' read low byte of data
  RETURN


' -------------------------
' Low Level I2C Subroutines
' -------------------------

' --- Start ---

I2C_Start:                                      ' I2C start bit sequence
  INPUT SDA
  INPUT SCL
  LOW SDA                                       ' SDA -> low while SCL high

Clock_Hold:
  DO : LOOP WHILE (SCL = 0)                     ' wait for device ready
  RETURN


' --- Transmit ---

I2C_TX_Byte:
  SHIFTOUT SDA, SCL, MSBFIRST, [i2cWork\8]      ' send byte to device
  SHIFTIN SDA, SCL, MSBPRE, [i2cAck\1]          ' get acknowledge bit
  RETURN


' --- Receive ---

I2C RX Byte Nak:
  i2cAck = Nak                                  ' no Ack = high
  GOTO I2C RX

I2C_RX_Byte:
  i2cAck = Ack                                  ' Ack = low

I2C RX:
  SHIFTIN SDA, SCL, MSBPRE, [i2cWork\8]         ' get byte from device
  SHIFTOUT SDA, SCL, LSBFIRST, [i2cAck\1]       ' send ack or nak
  RETURN

' --- Stop ---

I2C Stop:                                       ' I2C stop bit sequence
  LOW SDA
  INPUT SCL
  INPUT SDA                                     ' SDA --> high while SCL high
  RETURN
```