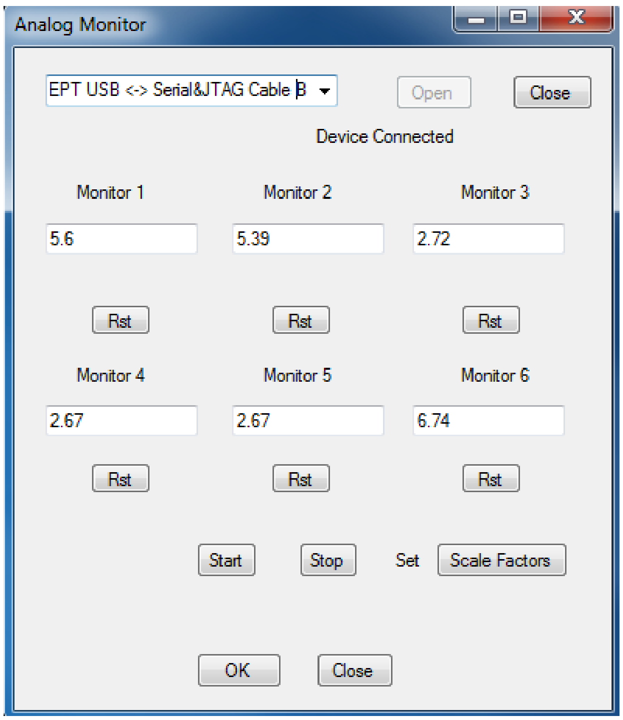
EARTH PEOPLE TECHNOLOGY, Inc

ANALOG MONITOR PROJECT FOR THE ARDUINO UNO
User Manual



The Analog Monitor Project is designed for EPT USB CPLD Development System. It samples all six of the analog inputs of the Arduino Uno and displays each of the values on the PC in real time.

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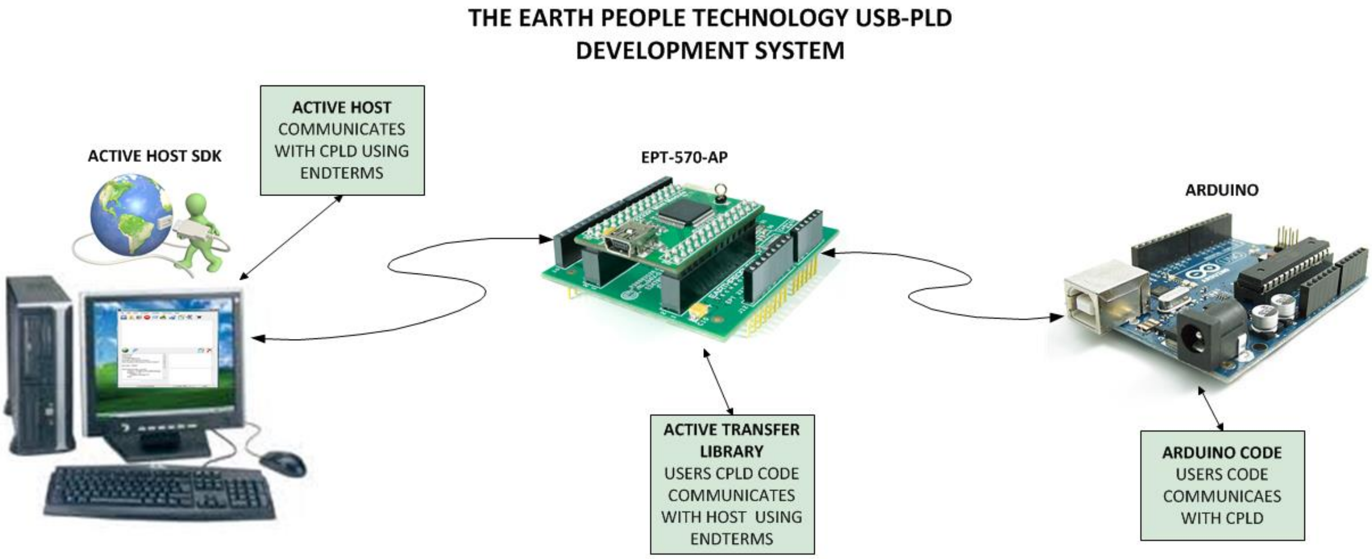
1 Analog Monitor Project Introduction

The Analog Monitor Project uses the Earth People Technology USB-CPLD development system hardware and the Arduino Uno connected to a Windows PC. The project software uses the Microsoft C# Express in conjunction with the Active Host dll.

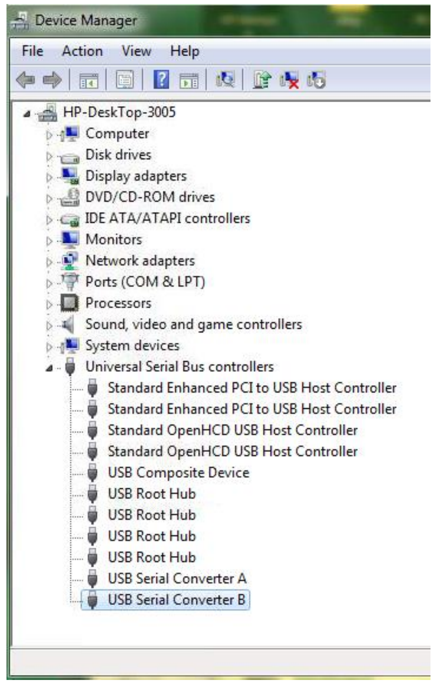


This User Manual will guide the user to create the Arduino code that will sample each of the Analog inputs and transfer the digitally converted sample to the CPLD. The user will be given instructions on creating the CPLD code that accepts each sample from the Arduino and transmits it via USB to the PC. The manual completes with instruction of how to create the C# application that will decode each sample and display on the screen along with the other five analog input samples.

This is an advanced project and not for beginners to the Arduino family. However, it does serve as an introduction to advanced programming techniques using Verilog for programming the CPLD and C# for programming the user interface on the PC. The first two sections provide a background for the PC and CPLD libraries.

1.1 Driver Installation

Follow the instructions in the EPT USB CPLD Development System User Manual to install all of the software and drivers for use with the hardware.



If the driver has been installed correctly, you can go to the Device Manager and click on the Universal Serial Bus controllers and see "USB Serial Converter A" and "USB Serial Converter B".

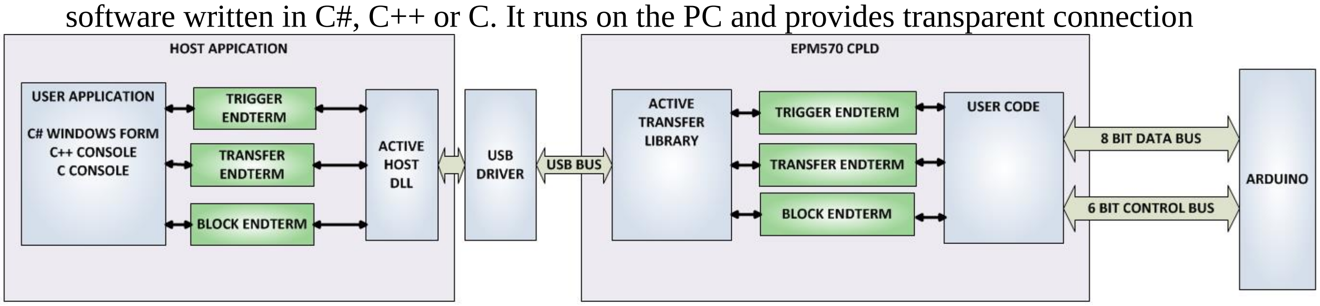
1.2 Software Installation

Follow the the instructions in the EPT USB CPLD Development System User Manual to install the following software:

- Altera Quartus II
- Microsoft C# Express
- Arduino Wiring IDE

1.3 Active Host EndTerms

The Active Host SDK is provided as a dll which easily interfaces to application software written in C#, C++ or C. It runs on the PC and provides transparent connection



from PC application code through the USB driver to the user CPLD code. The user code connects to "Endterms" in the Active Host dll. These Host "Endterms" have complementary HDL "Endterms" in the Active Transfer Library. Users have seamless bi-directional communications at their disposal in the form of:

- Trigger Endterm
- Transfer Endterm
- Block Endterm

User code writes to the Endterms as function calls. Just include the address of the individual module (there are eight individually addressable modules of each Endterm). Immediately after writing to the selected Endterm, the value is received at the HDL Endterm in the CPLD.

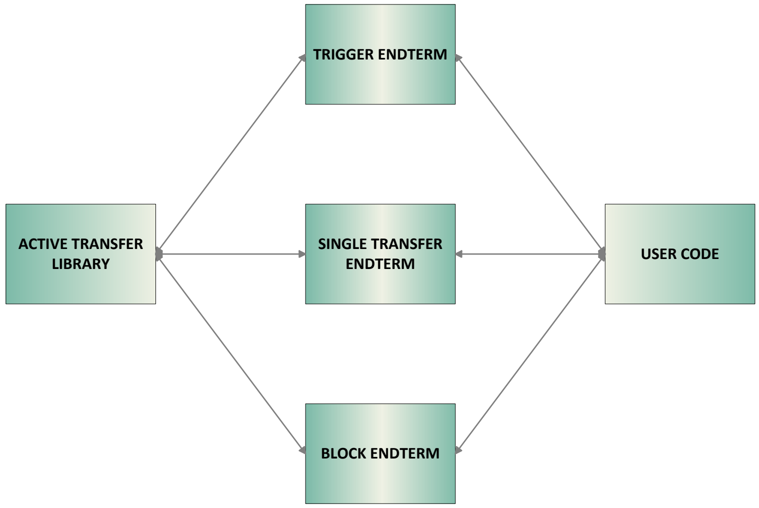
Receiving data from the CPLD is made simple by Active Host. Active Host transfers data from the CPLD as soon as it is available. It stores the transferred data into circular buffer. When the transfer is complete, Active Host invokes a callback function which is registered in the users application. This callback function provides a mechanism to transparently receive data from the CPLD. The user application does not need to schedule a read from the USB or call any blocking threads.

1.4 Active Transfer Library EndTerms

The Active Transfer Library is a portfolio of HDL modules that provides an easy to use yet powerful USB transfer mechanism. The user HDL code communicates with EndTerms in the form of modules. These EndTerm modules are commensurate with the Active Host EndTerms. There are three types of EndTerms in the Active Transfer Library:

- Trigger Endterm
- Transfer Endterm
- Block Endterm

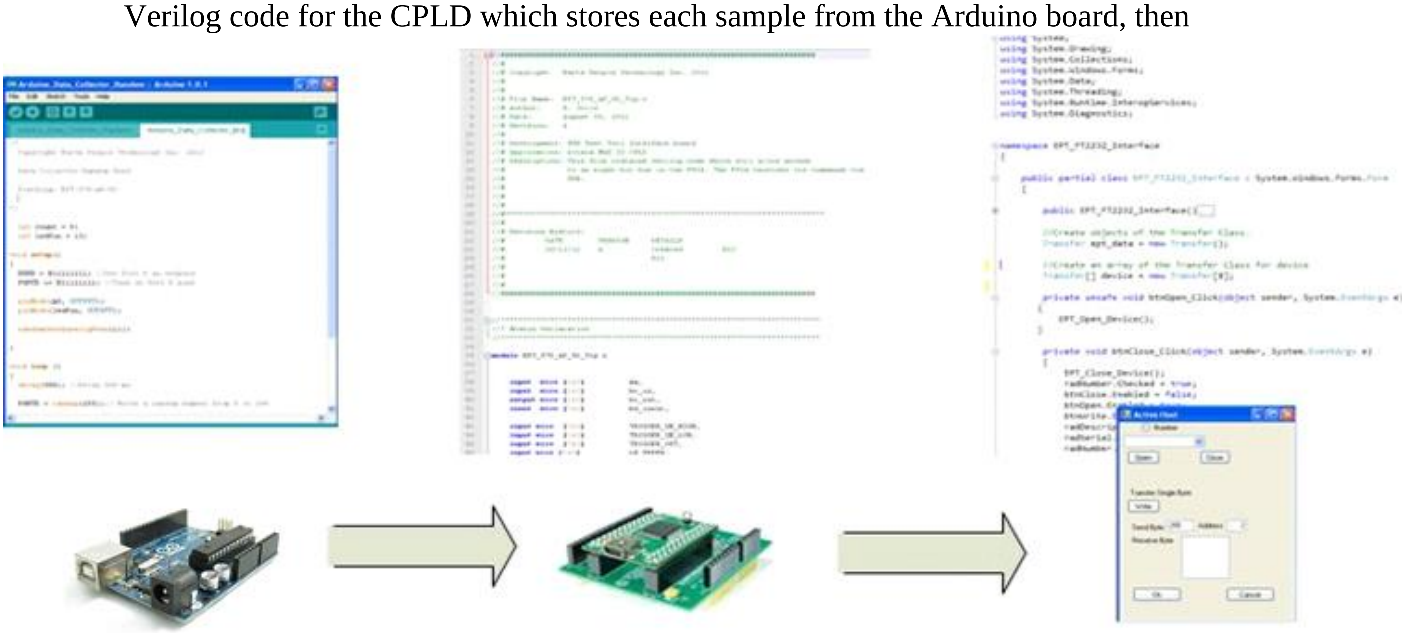
They each have a simple interface that the user HDL code can use to send or receive data across the USB. Writing to an EndTerm will cause the data to immediately arrive



at the commensurate EndTerm in the Active Host/user application. The transfer through the USB is transparent. User HDL code doesn't need to set up Endpoints or respond to Host initiated data requests. The whole process is easy yet powerful.

2 The Development Process

The development of the Analog Monitor Project starts with the Arduino. The user will write the code to sample each Analog input using the 10 bit ADC, then assert the write enable which initiates the read cycle on the EPT-570-AP board. The user will write the Verilog code for the CPLD which stores each sample from the Arduino board, then



initiates the write cycle to PC. Finally, the user will write the C# code to accept each byte from the EPT-570-AP board and assemble the bytes into the original 10 bit word and display it in the requisite textbox in a Windows Form.

2.1 Designing a Simple Analog Monitor Project

The Analog Monitor is an advanced project and not for beginners to the Arduino family. However, it does serve as an introduction to advanced programming techniques using Verilog for programming the CPLD and C# for programming the user interface on the PC. The user should be familiar with the beginners projects for the Arduino Uno. For an introduction to Verilog, go to:

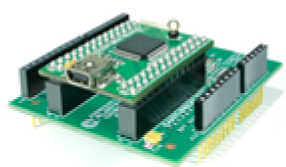
www.asic-world.com/verilog/intro1.html#Introduction

For an introduction to C#, go to:

http://www.homeandlearn.co.uk/csharp/csharp.html

2.2 Analog Monitor Project Equipment Needed

The equipment you will need for the Analog Monitor project is

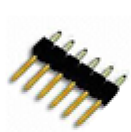


EARTH PEOPLE TECHNOLOGY EPT-570-AP-U2

ARDUINO UNO

USB MINI B CABLE

USB TYPE B CABLE



6 PIN 2.54 MM HEADER

10 PIN 2.54 MM HEADER

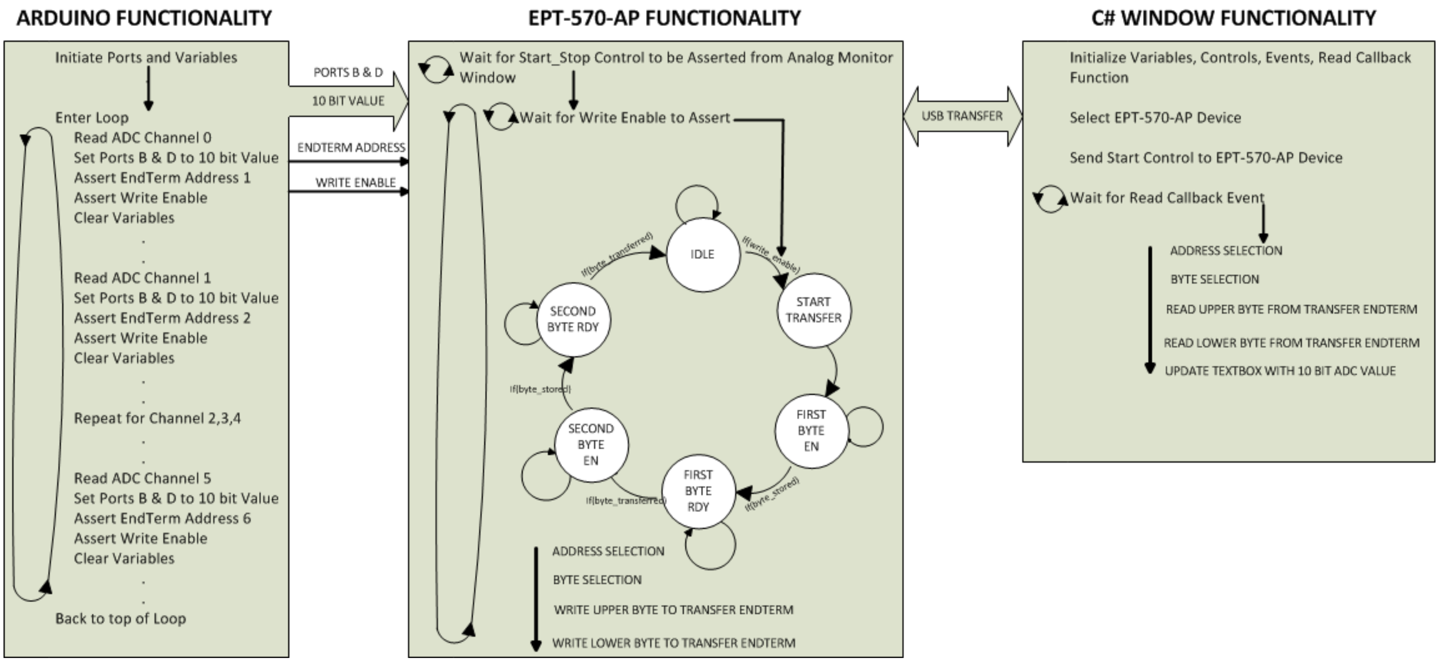
SIX 5 VOLT DC POWER SUPPLIES

SIX PAIR OF BANANA CLIP LEADS

- Earth People Technology EPT-570-AP-U2 board
- Arduino Uno Board
- PC running Windows 7 or equivalent, with 2 USB ports
- USB cable Type B
- USB cable Type Mini B
- 6 pin 2.54 mm Male Header
- 10 pin 2.54 mm Male Header
- 12 inches of 18 guage Wire
- 1 to 6 5VDC Power Supplies
- Six 1 to 2 Foot Red Banana to Clip Leads
- One 1 to 2 Foot Black Banana to Clip Lead
- Five Six Inch Red Banana to Banana Lead
- Five Six Inch Black Banana to Banana Lead

2.3 Analog Monitor Data Flow

The data flow for the Analog Monitor project is shown below. The Arduino initializes its ports and variables then enters the main loop() function. In the main loop, each analog channel is converted into a 10 bit word. The digitized value is set on the PORT B & D pins. Next, the EndTerm address is set and the Write Enable signal is asserted. The next instruction de-asserts the Write Enable and the next analog channel goes through the same process. At the end of the loop, all six channels have been digitized and the data sent to the CPLD



The CPLD does not need any initialization as the device is ready to operate soon after the power is applied. The data flow in the EPT-570-AP starts with a wait loop for the Start_Stop_Control signal to be asserted from the Control Register. Once this happens, the data flow will fall into the wait loop for the Write Enable. When the Write Enable asserts, the State Machine leaves the IDLE state and enters the START_TRANSFER state. In this state the EndTerm address will be selected and the 10 bit digitized value is stored locally. The state machine will immediately enter the FIRST_BYTE_EN state and initiate the lower byte (of the digitized value) transfer across the USB. This state will wait for this first byte to be accepted by the Active Transfer Library. Next, the FIRST_BYTE_RDY state is entered. In this state, the state machine will wait for the Active Transfer Library to complete the transfer. Next, the upper byte of the digitized value is transmitted across the USB in the same way as the lower byte in the SECOND_BYTE_EN and SECOND_BYTE_RDY states. When the upper byte transfer is complete, the state machine goes back into the IDLE state. The data flow waits in a loop for the Write Enable to assert again and start the process again.

The C# data flow on the PC starts with the initialization of variables, controls, events, and read callback functions. The Windows Form is displayed on the PC and the system registry is scanned for any Earth People Technology devices. Any devices that are found are added to the drop down box. The user must then select the available EPT device and click the Open control. This will select the device and allocate all memory needed for the Active Host EndTerms. Next, the user must click on the Start button. Clicking this button will send the control register value to the EPT-570-AP board. This value is sent in a message. The CPLD Control Register State Machine will decode this message and read the control register and assert the Start_Stop_Control signal. Once this signal is asserted, the CPLD will send the lower byte and upper byte messages to the

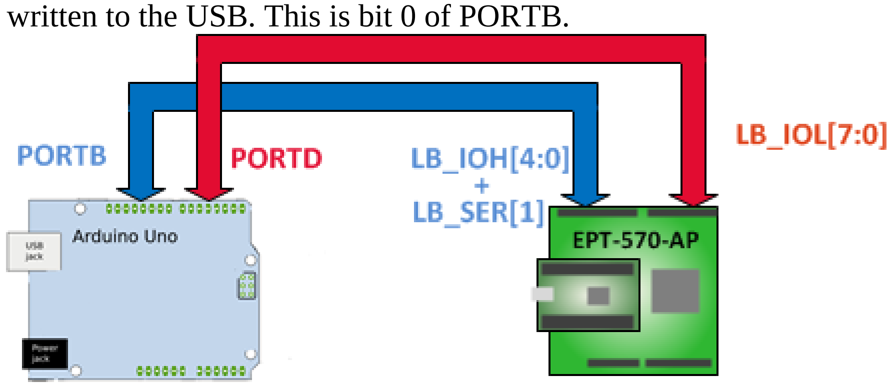
Active Host EndTerms. When bytes are received, the read callback function is called. The read callback will call the EPTParseReceive() function which calls the TransferOutReceive() function. In this function, the EndTerm address is selected and the upper byte is stored in the upper portion of a local variable. The next time the TransferOutReceive() is called, from the read callback, the EndTerm is selected and the lower byte is stored into the local variable. At this point the full digitized value is transferred from the CPLD EndTerm and is ready for display. The textbox is selected by the EndTerm address and is updated with the collected digitized value. The cycle repeats until the Stop button is pressed.

3 Arduino Analog Monitor Code

The first order of business is to layout the design. Start with the Arduino, and create a simple analog signal sampler using the “analogRead()” function. Send the sampled analog signal to the EPT-570_AP board using an address and an enable signal.

3.1 Select I/O’s for Fast Throughput on Arduino

PORTD is an 8 bit port that is used to connect the lower 8 bits of the sample to the input of the EPT-570-AP. Bits 8 and 9 of the sample are connected to bits 4 and 5 of PORTB. The address for the EndTerms is three bits and occupies bits 1, 2 and 3 of PORTB. There is also a one bit control line which will be used to inform the CPLD that a byte is ready to be written to the USB. This is bit 0 of PORTB.



Arduino Uno				Connects To	EPT-570-AP			
Signal	**Port**	**Pin**	**Connector**		**Connector**	**Pin**	**Port**	**Signal**
ADC Bits 7 to 0	D	7 to 0	IOL		J8	7 to 0	LB_IOL	analog_monitor_ lower_byte
ADC Bit 9	B	5	IOH		J10	4	LB_IOH	analog_monitor_ upper_byte(1)
ADC Bit 8	B	4	IOH		J10	1	LB_SER	analog_monitor_ upper_byte(0)
EndTerm Address Bit 2	B	3	IOH		J10	3	LB_IOH	analog_monitor_ address(2)
EndTerm	B	2	IOH		J10	2	LB_IOH	analog_monitor_

Address Bit 1								address(1)
EndTerm Address Bit 0	B	1	IOH		J10	1	LB_IOH	analog_monitor_address(0)
Write Enable	B	0	IOH		J10	0	LB_IOH	analog_monitor_en

Each port on the Arduino is controlled by three registers, which are also defined variables in the Arduino language. The DDR register, determines whether the pin is an INPUT or OUTPUT. The PORT register controls whether the pin is HIGH or LOW, and the PIN register reads the state of INPUT pins set to input with pinMode(). The maps of the ATmega328 chips show the ports.

DDR and PORT registers may be both written to, and read. PIN registers correspond to the state of inputs and may only be read.

PORTD maps to Arduino digital pins 0 to 7

DDRD - The Port D Data Direction Register - read/write
PORTD - The Port D Data Register - read/write
PIND - The Port D Input Pins Register - read only

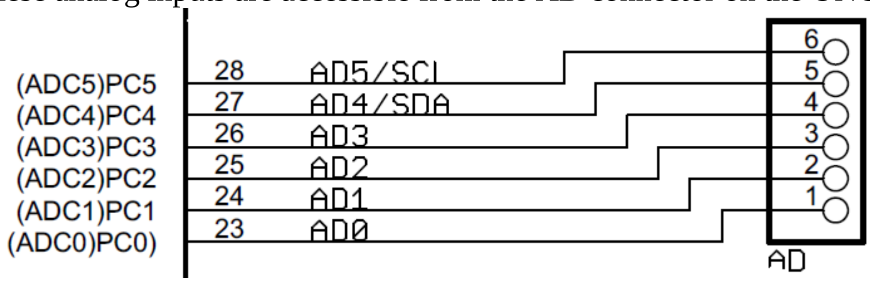
The ports and pins for the Analog Monitor Project project must be initialized in the setup() function. The setup function will only run once, after each powerup or reset of the Arduino board.

```
void setup()
{
  DDRD = B11111111; //Set Port D as outputs
  PORTD &= B11111111; //Turn on Port D pins

  DDRB = B00111111; //Set Port B as outputs
  PORTB &= B00000000; //Turn on Port B pins

}
```

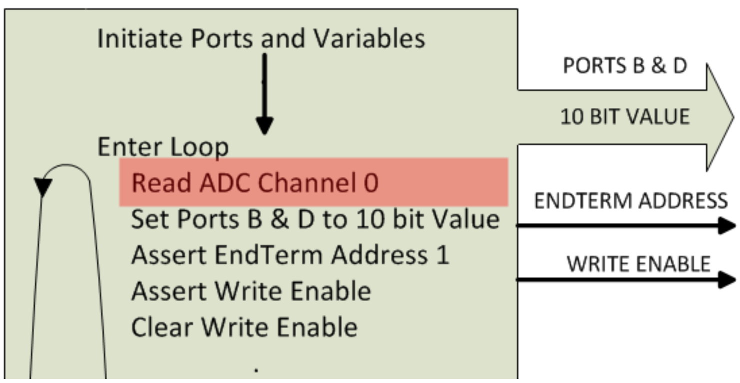
After the setup() function executes, the Arduino will enter the Loop() function and start to perform the reading of the analog signals. And the PORTB bit 0 pin will be used to latch the value on PORTD and PORTB pins into the CPLD.

3.1 Create Data Sampler

The analogRead() function is called to convert the analog signal on the given pin into a 10 bit digital word. The selections for the pin range from 0 to 5 for a total of six analog inputs. These analog inputs are accessible from the AD connector on the UNO.



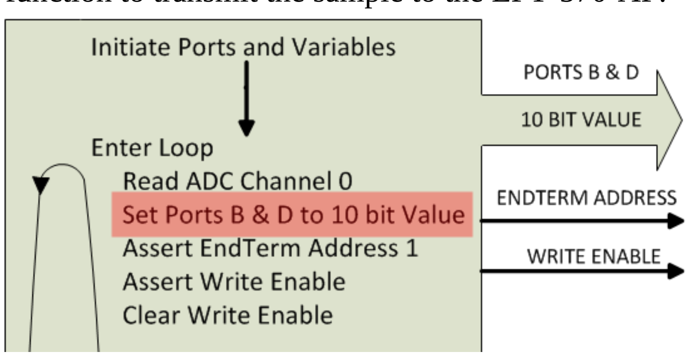
Calling the function analogRead(0) will convert the analog signal on the AD0 net into a 10 bit digital word. This word will be stored in a local variable in the Arduino code.



The next section will show the transmission of this value to the EPT-570-AP board. Note that the ADC output can be selected to be either 8 bits or 10 bits. The ADLAR bit in the ADMUX register will select if 10 bit or 8 bit precision is used. The ADC defaults to 10 bit precision.

3.1.1 Control Signals for the Analog Monitor

The 10 bit digitized value from the analogRead() function is applied to the PORT B & D pins. We will focus on keeping things fast on the Arduino. In order to do this, we will use the port write function to transmit the sample to the EPT-570-AP.

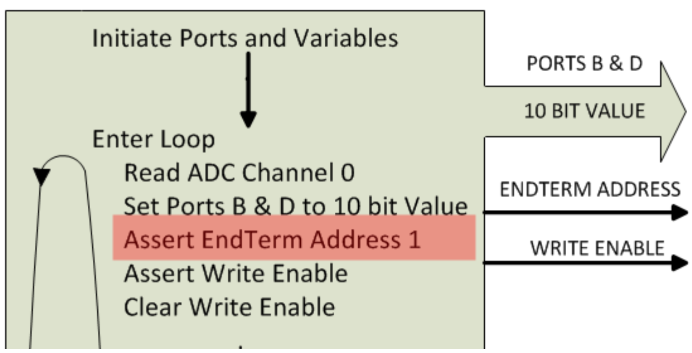


Using port writes is faster than using the built in functions in Arduino Processing. We will use the port write to transfer the 10 bit ADC sample and use it to set the address for the Active Transfer Library EndTerm and for the write enable.

```
// Read Analog Signal 0
AdcValue = analogRead(0);
PORTD = AdcValue;

UpperAdcValue = (AdcValue & 0x0300)>>4;
```

Here, notice that the PORTD is set to the value of AdcValue. This will naturally set the the bottom 8 bits of AdcValue to PORTD. To set the bits 8 and 9 of AdcValue to PORTB bits 4 and 5, we use a left shift of four bits. The left shift operator >> will shift everything in AdcValue to the left by four bits. We only want bits 8 and 9, so we mask off everything but bits 8 and 9, (AdcValue & 0x0300). Then apply the shift.

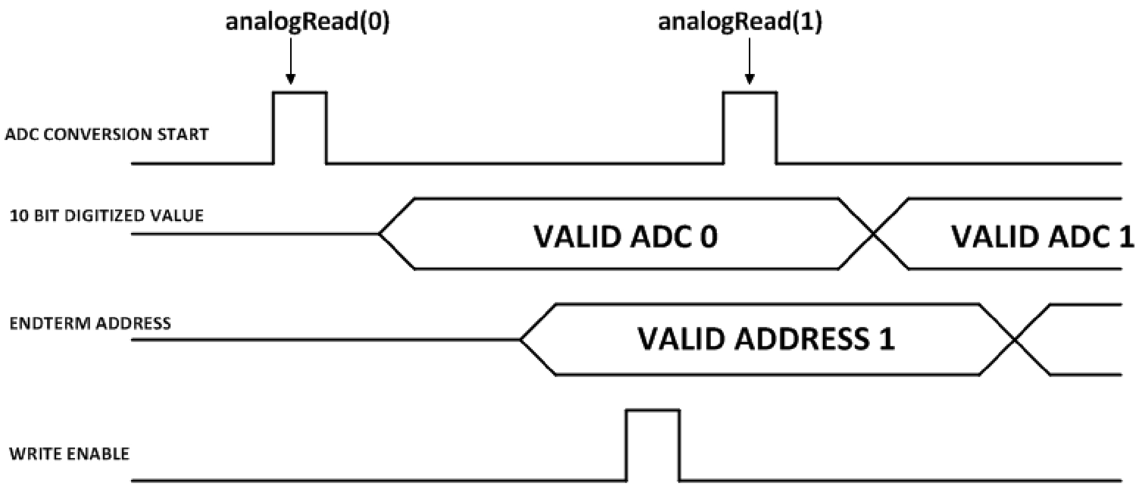
The Analog Monitor must assert an EndTerm Address and the Write Enable to cause the EPT-570-AP to process the digitized value.



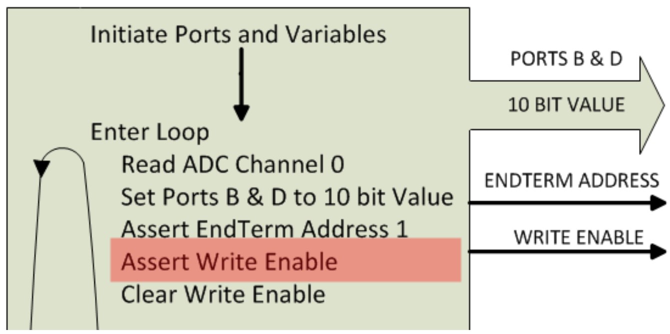
We will do this by first setting the address and the upper 2 bits of the digitized value on the output pins of PORTB. Then set Write Enable high. Finally, set Write Enable low.

```
UpperAdcValue = (AdcValue & 0x0300)>>4;

//Set the Address=1
PORTB = B00000010 | UpperAdcValue;
//Write Enable Pin High
PORTB = B00000011 | UpperAdcValue;
//De-assert the Write Enable Pin Address=1
PORTB = B00000010 | UpperAdcValue;
```

The signal timing shows the ADC Conversion Start for each ADC channel followed by setting the control signals.



Each time the Write Enable asserts and de-asserts, the cycle repeats with the next analogRead().



This continues for all six channels. The end of the loop() is reached, and the process starts all over again.

3.2 Coding the Arduino Analog Monitor

Now that we have the Analog Monitor ports, analog read, address selection and write enable defined , we can add all six channels in the loop() function and complete the Analog Monitor. The first instruction in the loop() is a delay. This delay is useful because the display to screen on the C# side takes several milliseconds. Because we are using a high speed USB, the Arduino takes only a few instructions to write to the EPT-570-AP. It will easily over fill the memory buffers in the C#. So, some delay is necessary.

```
void loop ()
{

  delay(10); //Delay 10 ms
```

The next instructions are to read the analogRead(0) function using channel 0 and store the value in the integer, AdcValue. The analogRead() function defaults to 10 bits. For the Arduino, we want to transmit the AdcValue in the fewest instructions possible. So, we will add the bottom byte of AdcValue to PORTD and the top two bits to pins 4 and 5 of PORTB. To do this, we have to shift bits 8 and 9 of AdcValue to bit 4 and 5 of PORTB. The code requires the right shift by 4.

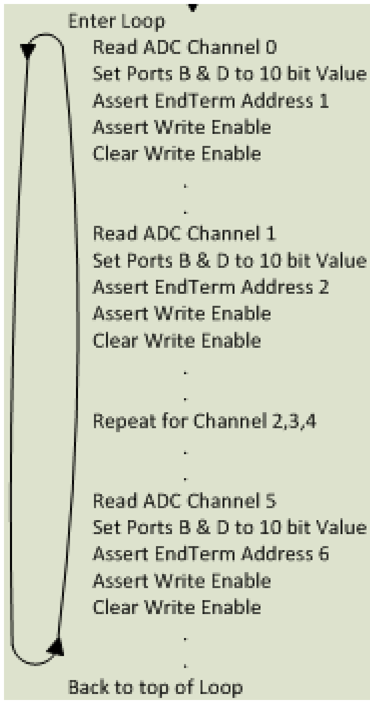
```
// Read Analog Signal 0
AdcValue = analogRead(0);
PORTD = AdcValue;

UpperAdcValue = (AdcValue & 0x0300)>>4;
```

With PORTD set to the lower byte of AdcValue and the upper two bits shifted into position, we will set PORTB to the address of the channel to transmit along with the upper bits. At this point we will keep Write Enable low.

```
//Set the Address=1
PORTB = B00000010 | UpperAdcValue;
//Write Enable Pin High
PORTB = B00000011 | UpperAdcValue;
//De-assert the Write Enable Pin Address=1
PORTB = B00000010 | UpperAdcValue;
```

In the next instruction, we set the Write Enable high. Immediately following this instruction, we set the Write Enable low. This will cause the entire 10 bit AdcValue to transmit in the fewest instructions. The CPLD is clocked at 66 MHz which allows it to transmit two bytes over the USB in less time than the Arduino. So, we let the CPLD do the heavy lifting.

The Analog Monitor code will continue with samling the next channel and transmitting its digitized value to the CPLD. Each iteration of the loop() function, samples all six Uno analog channels and transmits them to the CPLD. The delay of 10 milliseconds pauses the program each iteration.



So, the code looks like this:

```
/*
  Copyright Earth People Technology Inc. 2013

  Analog Monitor; Six Channel Analog
  Sampler

  Platform: EPT-570-AP-U2

*/

  int AdcValue;
  int UpperAdcValue;

void setup()
{
  DDRD = B11111111; //Set Port D as outputs
  PORTD &= B11111111; //Turn on Port D pins

  DDRB = B00111111; //Set Port B as outputs
  PORTB &= B00000000; //Turn on Port B pins

}

void loop ()
{

  delay(10); //Delay 10 ms

      // Read Analog Signal 0
      AdcValue = analogRead(0);
      PORTD = AdcValue;

      UpperAdcValue = (AdcValue & 0x0300)>>4;

      //Set the Address=1
      PORTB = B00000010 | UpperAdcValue;
      //Write Enable Pin High
      PORTB = B00000011 | UpperAdcValue;
      //De-assert the Write Enable Pin Address=1
      PORTB = B00000010 | UpperAdcValue;

      // Read Analog Signal 1
      AdcValue = analogRead(1);
      PORTD = AdcValue;
```

```
UpperAdcValue = (AdcValue & 0x0300)>>4;

//Set the Address=2
PORTB = B00000100 | UpperAdcValue;
//Write Enable Pin High
PORTB = B00000101 | UpperAdcValue;
//De-assert the Write Enable Pin Address=2
PORTB = B00000100 | UpperAdcValue;

// Read Analog Signal 2
AdcValue = analogRead(2);
PORTD = AdcValue;

UpperAdcValue = (AdcValue & 0x0300)>>4;

//Set the Address=3
PORTB = B00000110 | UpperAdcValue;
//Write Enable Pin High
PORTB = B00000111 | UpperAdcValue;
//De-assert the Write Enable Pin Address=3
PORTB = B00000110 | UpperAdcValue;

// Read Analog Signal 3
AdcValue = analogRead(3);
PORTD = AdcValue;

UpperAdcValue = (AdcValue & 0x0300)>>4;

//Set the Address=4
PORTB = B00001000 | UpperAdcValue;
//Write Enable Pin High
PORTB = B00001001 | UpperAdcValue;
//De-assert the Write Enable Pin Address=4
PORTB = B00001000 | UpperAdcValue;

// Read Analog Signal 4
AdcValue = analogRead(4);
PORTD = AdcValue;

UpperAdcValue = (AdcValue & 0x0300)>>4;
```

```
        //Set the Address=5
        PORTB = B00001010 | UpperAdcValue;
        //Write Enable Pin High
        PORTB = B00001011 | UpperAdcValue;
        //De-assert the Write Enable Pin Address=5
        PORTB = B00001010 | UpperAdcValue;

        // Read Analog Signal 5
        AdcValue = analogRead(5);
        PORTD = AdcValue;

        UpperAdcValue = (AdcValue & 0x0300)>>4;

        //Set the Address=6
        PORTB = B00001100 | UpperAdcValue;
        //Write Enable Pin High
        PORTB = B00001101 | UpperAdcValue;
        //De-assert the Write Enable Pin Address=6
        PORTB = B00001100 | UpperAdcValue;

}
```

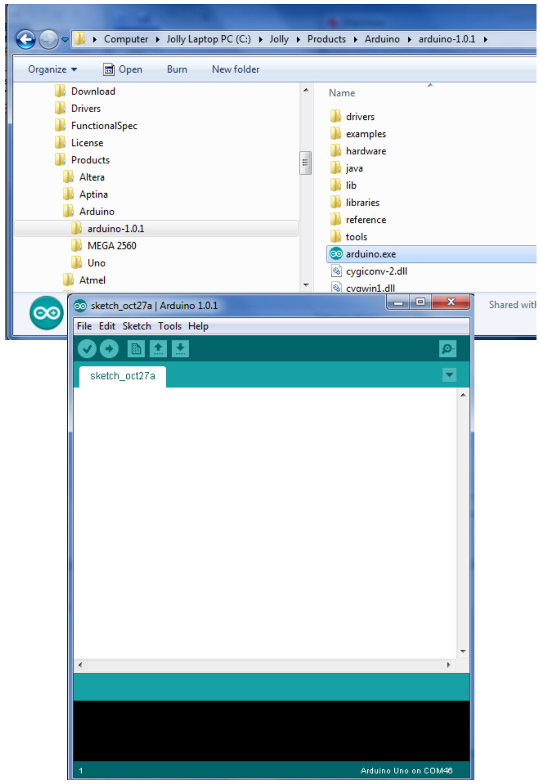
The Arduino code runs open loop. This means that the C# code and the CPLD cannot control or delay it. As soon as the code is loaded from flash, it initializes local variables, ports, and registers and starts running the instructions in the loop() function. The loop will continue to sample analog channels and transmit them to the EPT-570-AP until the power is removed.

3.3 Building Arduino Project

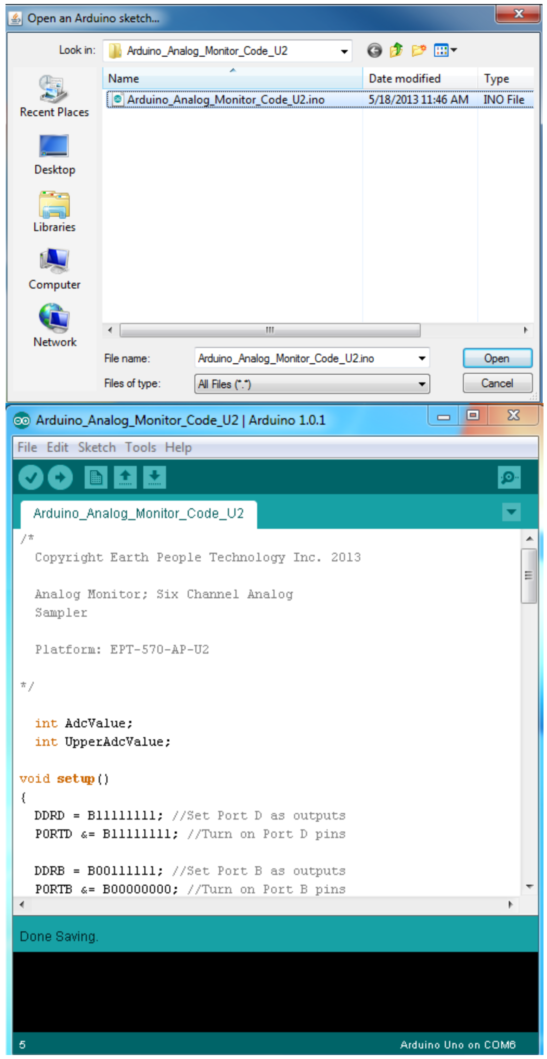
Building the Arduino project is the process of converting (compiling) the code you just wrote into machine level code that the processor can understand. The Arduino IDE is the software tool that does the compiling. The machine level code is a set of basic instructions that the processor uses to perform the functions the user code. Browse to the \Projects_Arduino\Arduino_Analog_Monitor\ Arduino_Analog_Monitor_Code_U2\ folder of the UNO_ANALOG_MONITOR_PROJECT_CD. Locate the Arduino_ Analog_Monitor_Code_U2.ino file.

To compile your code,

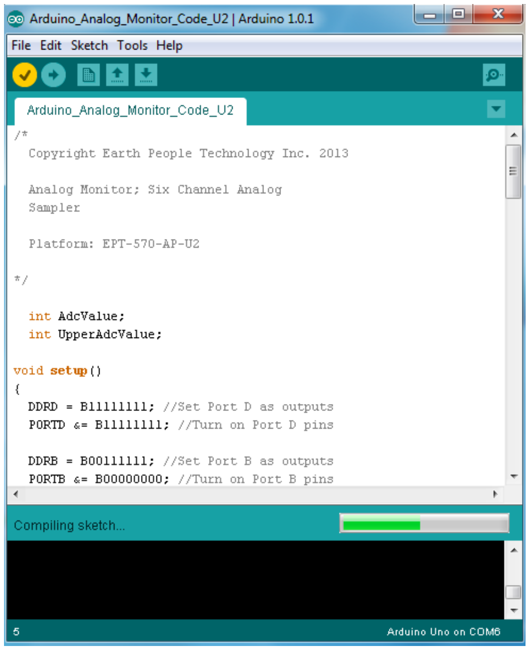
- Open up the Arduino IDE



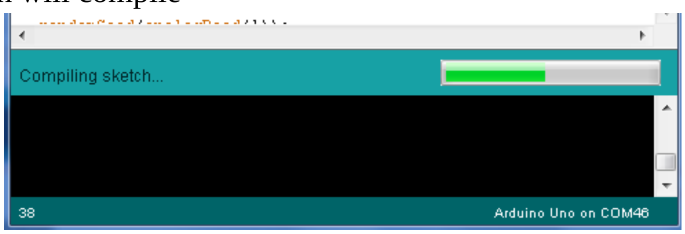
- Load your code into the Sketch.



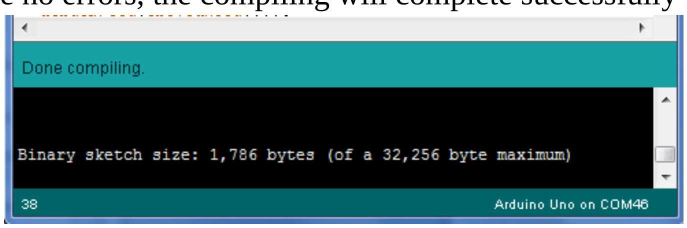
- Click the Verify button



- The sketch will compile



- If there are no errors, the compiling will complete successfully



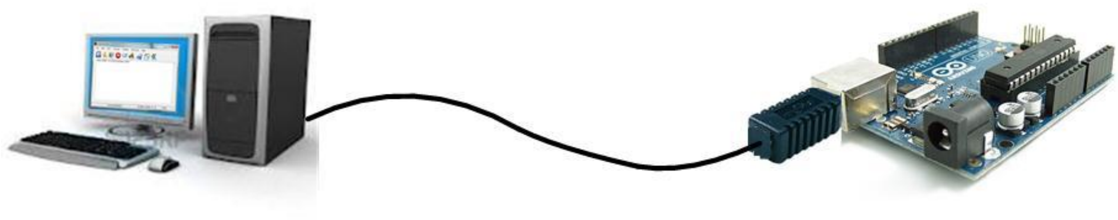
Now we are done with compiling and ready to program the Arduino

3.4 Programming the Arduino

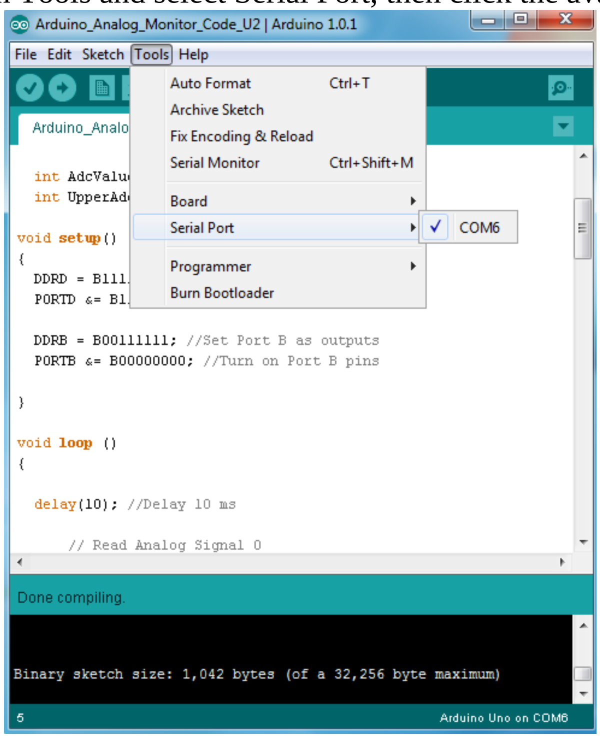
Programming the Arduino is the process of downloading the user’s compiled code into the Flash memory of the Atmel ATMega328 chip. Once the code is downloaded, the Arduino IDE resets the chip and the processor starts executing out of Flash memory.

To program the Arduino

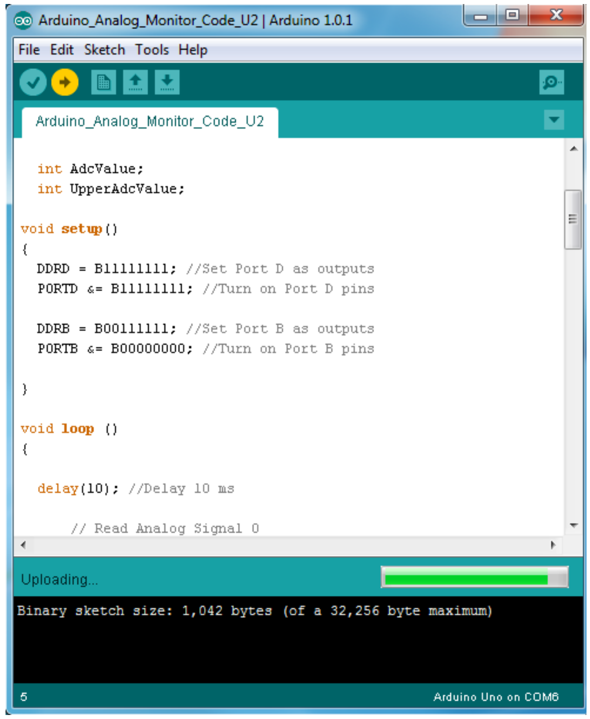
- Connect the USB cable from PC to Arduino



- Plug in your board and wait for Windows complete the driver installation process.
- Next, click on Tools and select Serial Port, then click the available port.



- To load the code, click on the Upload button.



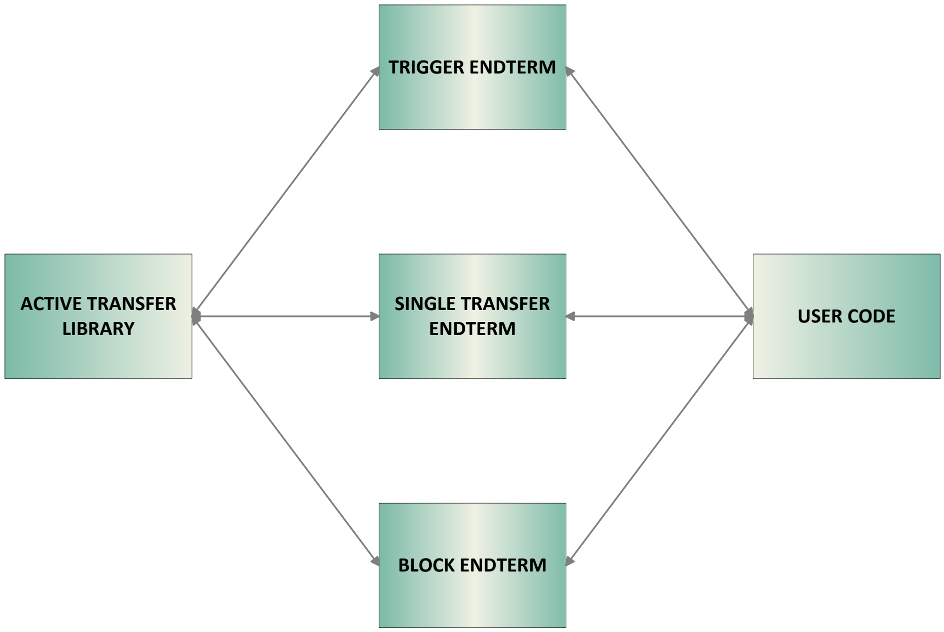
When the code has completed loading, the Arduino IDE will automatically command the processor to start executing the code. The Arduino is now ready for the EPT-570-AP.

4 CPLD Active Transfer EndTerms Coding

The EPT-570-AP will accept the digitized data sampled by the Arduino and transfer it to the PC. It is designed to plug directly into the Arduino Uno and there is no need for external wires to be added. The Active Transfer Library is used to send the data to the PC. The Active Transfer EndTerms are used to connect the Active Transfer Library to the user code. This makes it easy to transfer data to and from the PC via the USB. The user needs to create a state machine to control the transfer between the incoming data and the Active Transfer EndTerms.

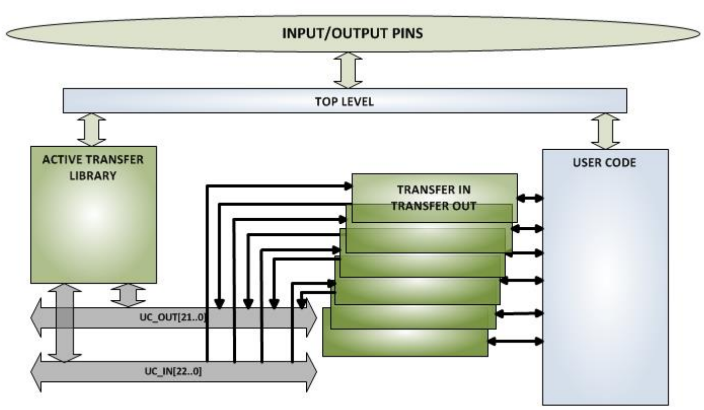
4.1 Define the User Design.

In this step we will define the user's code and include EndTerms and the EPT Active Transfer Library. The Active Transfer Library contains a set of files with a ".vqm" name extension which select particular operations to perform (e.g., byte transfer, block transfer, trigger).. The active_transfer_library.vqm file must be included in the top level file of the project. The EndTerms will connect to the active_transfer_library and provide a path to connect user code to the library. All of these files are available on the Earth People Technology Project CD.



We will build our CPLD project using Quartus II software from Altera. The primary file defining the user's CPLD project is named "EPT_570_AP_U2_Top.v". It defines the user code and connects the active_transfer_library and Endterms.

The Analog Monitor project needs to accept a 10 bit value that spans the J8 connector and the J10 connector. Three bits select the Transfer EndTerm to transmit on and a write enable bit is used to start a state machine which latches all values and transmits the digitized value. Because the active_transfer_library runs at 66 MHz we will need to add some code ensure that the slower Write Enable signal from the Arduino can latch the data into the Transfer EndTerm.



The first thing to do is to create a top level file for the project. The top level file will include the input and outputs for the CPLD. These are declared according to the Verilog syntax rules. We won't go through all the rules of Verilog here, but feel free to explore the language more thoroughly at:

www.asic-world.com/verilog/intro1.html#Introduction

4.2 Select the Input/Outputs

We need to set the inputs and outputs for EPT_570_AP_U2_Top.v. The I/O nets will stay the same for all EPT projects. All of the usable pins are connected to traces on the EPT-570-AP board and serve specific functions. However, the pins that connect to the Arduino can be set to either inputs or outputs. It is in the port section of the Verilog module that the Arduino pins can be set. For the Analog Monitor project, we will read from the J8 and J10 connectors. So, we set these as inputs. Since the analog inputs to the Arduino are on the J9 connector, we will set it up as inputs. The following nets are used to connect to the EPT-570-AP connectors.

Arduino Uno					**EPT-570-AP**			
Signal	**Port**	**Pin**	**Connector**		**Connector**	**Pin**	**Port**	**Signal**
ADC Bits 7 to 0	D	7 to 0	IOL	**Connects To**	J8	7 to 0	LB_IOL	analog_monitor_ lower_byte
ADC Bit 9	B	5	IOH		J10	4	LB_IOH	analog_monitor_ upper_byte(1)
ADC Bit 8	B	4	IOH		J10	1	LB_SER	analog_monitor_ upper_byte(0)
EndTerm Address Bit 2	B	3	IOH		J10	3	LB_IOH	analog_monitor_ address(2)
EndTerm Address Bit 1	B	2	IOH		J10	2	LB_IOH	analog_monitor_ address(1)
EndTerm Address Bit 0	B	1	IOH		J10	1	LB_IOH	analog_monitor_ address(0)
Write Enable	B	0	IOH		J10	0	LB_IOH	analog_monitor_ en

Each net is followed by the net type wire or reg. If it is a vector, the array description must be added.

```
module EPT_570_AP_U2_Top (


    input  wire [1:0]          aa,
    input  wire [1:0]          bc_in,
    output wire [2:0]          bc_out,
    inout  wire [7:0]          bd_inout,

    input wire   [1:0]          LB_SER,       //XIOH -- J10
    input wire   [5:0]          LB_AD,        //AD   -- J9
    input wire   [7:0]          LB_IOH,       //XIOH -- J10
    input wire   [7:0]          LB_IOL,       //XIOL -- J8


    //Transceiver Control Signals
    output wire                TR_DIR_1,
    output reg                 TR_OE_1,

    output wire                TR_DIR_2,
    output reg                 TR_OE_2,

    output wire                TR_DIR_3,
    output reg                 TR_OE_3,


    input wire                SW_USER_1,
    input wire                SW_USER_2,

    output wire [3:0]          LED
    );
```

4.3 Registers and Parameters

Next, the parameter's are defined. These are used as constants in the user code.

```
//-----------------------------------------------
// Control Register State Machine Parameters
//-----------------------------------------------

//Header Bytes for the Transfer Loopback detection
parameter                   TRANSFER_CONTROL_BYTE1 = 8'h5A;
parameter                   TRANSFER_CONTROL_BYTE2 = 8'hC3;
parameter                   TRANSFER_CONTROL_BYTE3 = 8'h7E;

//State Machine Transfer Loopback detection
parameter                   TRANSFER_CONTROL_IDLE = 0,
                            TRANSFER_CONTROL_HDR1 = 1,
                            TRANSFER_CONTROL_HDR2 = 2,
                            TRANSFER_DECODE_BYTE   = 3,
                            TRANSFER_CONTROL_SET  = 4;

//----------------------------------------------
// USB Transfer State Machine Parameters
//----------------------------------------------
 parameter   IDLE                            = 0,
             START_TRANSFER                  = 1,
             FIRST_BYTE_EN                   = 2,
             FIRST_BYTE_RDY                  = 3,
             SECOND_BYTE_EN                  = 4,
             SECOND_BYTE_RDY                 = 5;

  //----------------------------------------------
 // Global Reset Parameters
 //----------------------------------------------
parameter                   GLOBAL_RESET_COUNT = 12'h09c8;
```

Next is the Internal Signal and Register Declarations.

```
//****************************************************************************
//* Internal Signals and Registers Declarations
//****************************************************************************
    wire                        CLK_66;
    wire                        RST;

    wire [23:0]                 UC_IN;
    wire [21:0]                 UC_OUT;

    //Finite State Machine control registers
    reg      [5:0]                   state, next;

    //LED registers
    reg                         led_reset;

    //Switch registers
    reg                         switch_reset;

    //Transfer registers
    reg                         transfer_out_reg;
    wire                        transfer_in_received;
    wire [7:0]                  transfer_in_byte;
    wire  [7:0]                 transfer_out_byte;
    reg  [3:0]                  transfer_to_host_counter;
    reg  [3:0]                  transfer_to_host_state;

    //Transfer Control registers
    reg                         transfer_in_received_reg;
    reg  [3:0]                  transfer_control_state;
    reg  [7:0]                  transfer_control_byte;
```

```
//Transfer Control registers
reg                         transfer_in_received_reg;
reg   [3:0]                 transfer_control_state;
reg   [7:0]                 transfer_control_byte;

//Transfer Write from Arduino
reg                         transfer_write_reg;
reg                         transfer_write;
reg   [9:0]                 transfer_write_data;
reg   [7:0]                 analog_monitor_lower_byte;
reg   [1:0]                 analog_monitor_upper_byte;
reg   [2:0]                 transfer_address;
reg   [2:0]                 analog_monitor_address;
reg                         analog_monitor_en;

//Reset signals
wire                        reset;
reg [11:0]                  reset_counter;
reg                         reset_signal_reg;

//Input/Output Signals
reg                         start_stop_cntrl;

//Reset signals
wire                        reset;
reg [11:0]                  reset_counter;
reg                         reset_signal_reg;

//Input/Output Signals
reg                         start_stop_cntrl;

//Control Signals for Active Transfer Endterms
reg   [5:0]                 start_transfer_array;


reg   [5:0]                 transfer_out;
wire  [5:0]                 transfer_busy_array;

//Registers to control the order of byte
//written to the PC
reg                         first_byte_complete;
reg                         second_byte_complete;
```

4.4 Assignments

Next, add the assignments. These assignments will set the direction of the bus transceivers that interface to the Arduino I/O's. The transceivers also include an output enable bit.

```
//****************************************************************************
//*     Signal Assignments
//****************************************************************************
 assign              TR_DIR_1  = 1'b1; //1 = A to B; 0 = B to A

  assign             TR_DIR_2  = 1'b1; //1 = A to B; 0 = B to A

  assign             TR_DIR_3  = 1'b1; //1 = A to B; 0 = B to A

  //Clock and Reset
  assign             CLK_66 = aa[1];
  assign             RST = reset;
  assign             reset = reset_signal_reg;

  //Transfer registers
  //assign             transfer_out = transfer_write;
  assign             transfer_out_byte = (state[START_TRANSFER] | state[FIRS

  //LED3 is used to signify to the  user that the Start
  //switch is enabled
  assign              LED[3] =  ~(transfer_out_1 | transfer_out_2 | transfer

  assign             LED[2:0] = ~transfer_address;
```

4.5 Reset Circuit

The reset signal is generated by a counter that starts counting upon power up. When the counter reaches GLOBAL_RESET_COUNT.

```
//*************************************************
//*     Reset Signal
//*************************************************
    always @(posedge CLK_IN or negedge aa[0])
    begin
      if(!aa[0])
      begin
            reset_signal_reg <= 1'b0;
            reset_counter <= 0;
      end
      else
      begin
        if( reset_counter < GLOBAL_RESET_COUNT )
        begin
            reset_signal_reg <= 1'b0;
            reset_counter <= reset_counter + 1'b1;
        end
        else
        begin
            reset_signal_reg <= 1'b1;
        end
      end
```

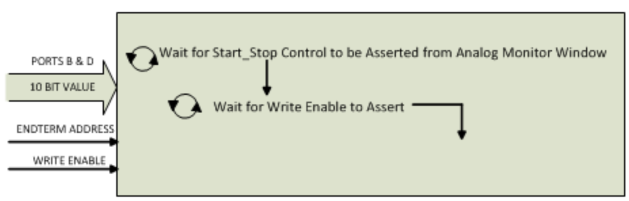
4.6 Input Registers

The section labled “Register the Inputs” applies the inputs from the Arduino to clocked registers. This will eliminate any noise on these inputs from propagating through to the state machines of the CPLD.

```
//-----------------------------------------------
// Register the inputs
//-----------------------------------------------
always @(posedge CLK_66 or negedge RST)
begin
    if(!RST)
    begin
        analog_monitor_en <= 1'b0;
        analog_monitor_lower_byte <= 0;
        analog_monitor_upper_byte <= 0;
        analog_monitor_address <= 0;
    end
  else
  begin
        analog_monitor_en <= LB_IOH[0];
        analog_monitor_lower_byte <= LB_IOL;
        analog_monitor_upper_byte <= {LB_IOH[4],LB_SER[1]};
        analog_monitor_address <= LB_IOH[3:1];
  end
end
```

4.7 Start/Stop and Write Enable detection

Next, we will add the transfer detection signal from the Arduino. This block will sample the Write Enable signal and wait for it to go high.



It is also used to provide start/stop control for the CPLD code. This block will use four registers to control the data and starting the state machine.

- transfer_write_reg –This is a latch register to hold the state of the Write Enable.
- transfer_write –This register is used to start the state machine and initiate the multi byte write to the PC.
- transfer_write_data –This is a 10 bit register to hold the value of the analog sample from the Arduino.
- transfer_address – 8 bit register to hold the EndTerm address from the Arduino.

The start_stop_cntrl signal is monitored every clock cycle. If it is sampled high, the output enables of the 74LVC4245 transceivers are set low and the outputs become active. When start_stop_cntrl goes low, the output enables of the 74LVC4245 transceivers are set high and sets the outputs to inactive.

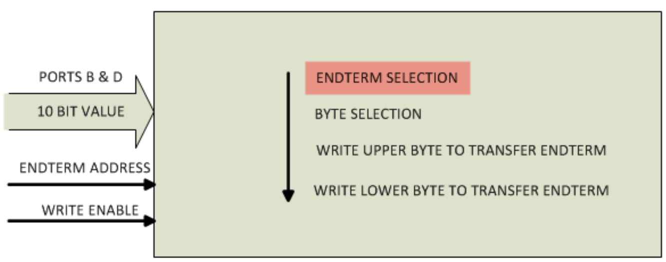
This block will compare the input signal on analog_monitor_en to a high. The analog_monitor_en is the registered version of LB_IOH[0]. When bit goes high, the priority encoder goes into statement 1 and sets transfer_write_reg and transfer_write high and latches the value on the analog_monitor_upper_byte and analog_monitor_lower_byte to the transfer_write_data register. The analog_monitor_address will be set to transfer_address. By setting transfer_write_reg high, the priority encoder goes into statement 2 which will set transfer_write register to low and stay in statement 2 of the priority encoder. When the analog_monitor_en signal goes low, the encoder will reset transfer_write_reg and transfer_write to low. The encoder goes back to waiting for the analog_monitor_en to assert high.

```
//-----------------------------------------------
// Detect Transfer From Arduino using the enable:
// LB_IOH[0]
//-----------------------------------------------
 always @(posedge CLK_66 or negedge RST)
 begin
    if (!RST)
    begin
        transfer_write_reg <= 1'b0;
        transfer_write <= 1'b0;
        transfer_write_data <= 0;
        transfer_address <= 0;
        TR_OE_1  = 1'b1;
        TR_OE_2  = 1'b1;
        TR_OE_3  = 1'b1;
    end
    else
    begin
        if(start_stop_cntrl)
        begin
            TR_OE_1  = 1'b0;
            TR_OE_2  = 1'b0;
            TR_OE_3  = 1'b0;
            if(analog_monitor_en & !transfer_write_reg)
            begin
                transfer_write_reg <= 1'b1;
```

```
                transfer_write <= 1'b1;
                transfer_address <= analog_monitor_address
                transfer_write_data <= {analog_monitor_uppe
            end
            else if(analog_monitor_en & transfer_write_re
            begin
                transfer_write_reg <= 1'b1;
                transfer_write <= 1'b0;
            end
            else if(!analog_monitor_en & transfer_write_re
            begin
                transfer_write_reg <= 1'b0;
                transfer_write <= 1'b0;
            end
        end
        else
        begin
            TR_OE_1   = 1'b0;
            TR_OE_2   = 1'b1;
            TR_OE_3   = 1'b1;
        end
    end
end
```

4.8 EndTerm Selection

The Analog Monitor Project includes the use of six Active Transfer EndTerms. Each EndTerm must have an address.



When the user code is ready to transmit a byte to the EndTerm, he must assert the start_transfer port of the module. Each of Active_Transfer EndTerms has its own dedicated net to pass to the start_transfer port. These nets are:

```
//Control Signals for Active Transfer Endterms
reg  [5:0]                start_transfer_array;
```

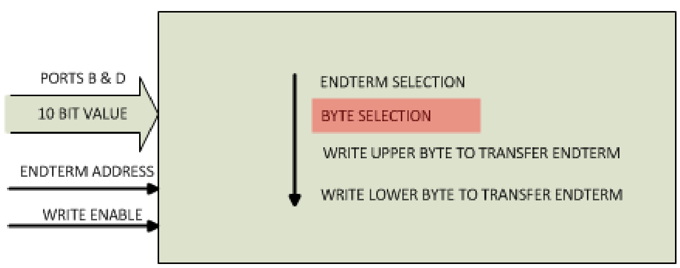
This s a vector register with a range of 5 to 0. So, six individual signals can be asserted to start the transfer to any of six Active_Transfer EndTerms. These nets are exclusively selected by using the address passed from the Arduino. This selection is performed using a case statement. We use an intermediate register vector to capture the address, then later apply the storage vector results to the start_transfer_array. The transfer_address vector is stored in the Transfer Detection block above. The EndTerm selection is only performed when the USB Transfer state machine is in the START_TRANSFER state.

```
//-----------------------------------------------
// Select the Transfer EndTerm using the address
// from the Arduino
//-----------------------------------------------
 always @(posedge CLK_66 or negedge RST)
 begin
     if(!RST)
     begin
         transfer_out <= 0;
     end
     else
     begin
         if(state[START_TRANSFER])
         begin
             case(transfer_address)
             3'h0:
             begin
                 transfer_out <= 0;
             end
            3'h1:
             begin
                 transfer_out <= 6'h01;
             end
             3'h2:
             begin
                 transfer_out <= 6'h02;
             end
             3'h3:
             begin
```

```
                        transfer_out <= 6'h04;
                    end
                    3'h4:
                    begin
                        transfer_out <= 6'h08;
                    end
                    3'h5:
                    begin
                        transfer_out <= 6'h10;
                    end
                    3'h6:
                    begin
                        transfer_out <= 6'h20;
                    end
                    default:
                    begin
                        transfer_out <= 6'h00;
                    end
                    endcase
                end
            end
        end
```

4.9 Upper/Lower Byte Selection

The “Transfer Upper/Lower byte using selected Active Transfer EndTerm” block selects the appropriate byte from the stored digitized sample and asserts the start_transfer_array index. The EndTerm address was selected in the “Select the Transfer EndTerm…” block.



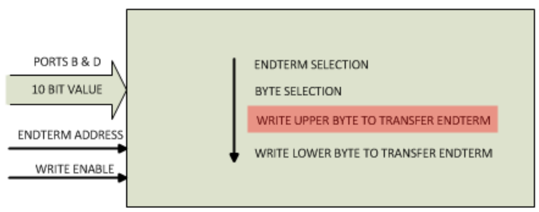
This block will require three registers:

- first_byte_complete – used to indicate to the USB Transfer state machine that the upper byte has been transferred to the Active Transfer EndTerm.
- second_byte_complete– used to indicate to the USB Transfer state machine that the lower byte has been transferred to the Active Transfer EndTerm.
- start_transfer_array – this is a six bit vector used to accept the address of the EndTerm selected in the “Select the Transfer EndTerm…” block (transfer_out).

The block is a conditional branch statement that uses the following states from the USB Transfer state machine to branch:

```
FIRST_BYTE_EN                 = 2,
FIRST_BYTE_RDY                = 3,
SECOND_BYTE_EN                = 4,
SECOND_BYTE_RDY               = 5;
```

1. After analog_monitor_en is asserted, the state machine will reach state[FIRST_BYTE_EN]. In this state the signal, first_byte_complete, will go high and the start_transfer_array is set to the EndTerm selected in the "Select the Transfer EndTerm…" block. This is the transfer_out vector.



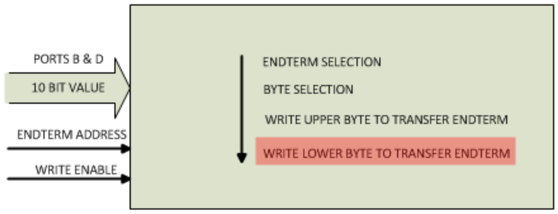
Each bit of start_transfer_array will cooresрnd to exactly one EndTerm and keep the rest de-asserted. In this conditional branch the selected EndTerm will transfer the lower byte on its transfer_to_host port. The second_byte_complete signal is used as a conditional branch to leave state[SECOND_BYTE_EN] and enter state[SECOND_BYTE_RDY]. Byte selection is performed using an assign statement to the transfer_out_byte:

```
//Transfer registers
assign          transfer_out_byte = (state[START_TRANSFER] | state[FIRST_BYTE_EN] |
                state[FIRST_BYTE_RDY] ? {6'h0,transfer_write_data[9:8]} : (state[SECOND_BYTE_EN] |
                state[SECOND_BYTE_RDY]) ? transfer_write_data[7:0] : 8'hz);
```

2. EndTerm selection of transfer_out. The start_transfer_array allows only one bit to be high at one time. This will allow only one EndTerm to transfer the upper byte on its transfer_to_host port. The first_byte_complete signal is used as a conditional branch to leave state[FIRST_BYTE_EN] and enter state[FIRST_BYTE_RDY] in the USB Transfer state machine.

3. The next conditional branch is reached when first_byte_complete goes high and state[FIRST_BYTE_EN] is high. In this state, the start_transfer_array is set to zero.

4. The third conditional branch is reached when state[FIRST_BYTE_EN] is low and signals that the upper byte transfer is complete and the state machine has moved to another state.



5. The next conditional branch is reach when second_byte_complete is low and state[SECOND_BYTE_EN] is high. In this state the signal second_byte_complete will go high and the start_transfer_array will transfer the lower byte on its transfer_to_host port. The second_byte_complete signal is used as a conditional branch to leave state[SECOND_BYTE_EN] and enter state[SECOND_BYTE_RDY].

6. The next conditional branch is reached when second_byte_complete goes high and state[SECOND_BYTE_EN] is high. In this state, the start_transfer_array is set to zero.

7. The third conditional branch is reached when state[SECOND_BYTE_EN] is low and signals that the upper byte transfer is complete and the state machine has moved to another state.

4.10 Transfer Control Register State Machine

The start_stop_cntrl signal is set by using the TRANSFER_CONTROL state machine in the following section. So, if the start_stop_cntrl signal is set, the CPLD code will enter the conditional branch code and wait for the Write Enable signal to assert.

Next, we add the TRANSFER_CONTROL state machine to read the Control Register from the Host PC using the active_transfer EndTerm. This state machine will decode the 8 bit control register only after a sequence of three 8 bit bytes in the order of 0x5a, 0xc3, 0x7e. The operation of the state machine is as follows.

1. The TRANSFER_CONTROL state machine will stay in the idle state of the parallel encoder until a byte from the active_transfer transfer_to_device register receives a 0x5a.
2. This will cause the transfer_control_state to be changed to TRANSFER_CONTROL_HDR1.
3. The state machine will stay in the TRANSFER_CONTROL_HDR1 state until the next byte is read from the active_transfer.
4. If the byte from transfer_to_device is a 0xc3, the transfer_control_state will be changed to TRANSFER_CONTROL_HDR2.
5. If the byte from transfer_to_device is not a 0xc3, the transfer_control_state will go back to idle.

6. In the TRANSFER_CONTROL_HDR2 state , the state machine will stay in this state until the next byte from the active_transfer is received.
7. If the byte from transfer_to_device is a 0x7e, the transfer_control_state will be changed to TRANSFER_DECODE_BYTE.
8. If the byte from transfer_to_device is not a 0x7e, the transfer_control_state will go back to idle.
9. In the TRANSFER_DECODE_BYTE state , the state machine will stay in this state until the next byte from the active_transfer.
10. The next byte transferred from active_transfer will be decoded as the Control Register.

The bits of the Control Register are defined below.

Register	**Bits**	**Description**	**Assertion**
Control	0	Start Stop Cntrl	High
	1	Not Used	
	2	LED Reset	High
	3	Switch Reset	High
	4	Transfer In Loop Back	High
	5	Not Used	
	6	Not Used	
	7	Not Used	
	7	Not Used	

```
//-------------------------------------------------
// State Machine: Control Register from Transfer In
//-------------------------------------------------
 always @(posedge CLK_IN or negedge RST)
 begin
     if (!RST)
     begin
         transfer_in_received_reg <= 1'b0;
         transfer_control_state <= TRANSFER_LOOPBACK_IDLE;
         transfer_in_loop_back <= 1'b0;
         led_reset <= 1'b0;
         switch_reset <= 1'b0;
     end
     else
     begin
         if(transfer_in_received & !transfer_in_received_reg)
         begin
             transfer_in_received_reg <= 1'b1;
             case(transfer_control_state)
             TRANSFER_CONTROL_IDLE:
                 if((transfer_in_byte == TRANSFER_CONTROL_BYTE1))
                     transfer_control_state <= TRANSFER_CONTROL_HDR1;
                 else if((transfer_in_byte != TRANSFER_CONTROL_BYTE1))
                     transfer_control_state <= TRANSFER_CONTROL_IDLE;
                 else
                     transfer_control_state <= TRANSFER_CONTROL_IDLE;
             TRANSFER_CONTROL_HDR1:
                 if((transfer_in_byte == TRANSFER_CONTROL_BYTE2))
                     transfer_control_state <= TRANSFER_CONTROL_HDR2;
                 else if((transfer_in_byte != TRANSFER_CONTROL_BYTE2))
```

```
                    transfer_control_state <= TRANSFER_CONTROL_IDLE;
                else
                    transfer_control_state <= TRANSFER_CONTROL_HDR1;
            TRANSFER_CONTROL_HDR2:
                if((transfer_in_byte == TRANSFER_CONTROL_BYTE3))
                    transfer_control_state <= TRANSFER_DECODE_BYTE;
                else if((transfer_in_byte != TRANSFER_CONTROL_BYTE3))
                    transfer_control_state <= TRANSFER_CONTROL_IDLE;
                else
                    transfer_control_state <= TRANSFER_CONTROL_HDR2;
            TRANSFER_DECODE_BYTE:
            begin
                transfer_in_loop_back <= transfer_in_byte[0];
                led_reset <= transfer_in_byte[2];
                switch_reset <= transfer_in_byte[3];
                transfer_loopback_state <= TRANSFER_LOOPBACK_SET;
            end
            TRANSFER_CONTROL_SET:
            begin
                transfer_control_state <= TRANSFER_CONTROL_IDLE;
            end
            endcase
        end
        else if(!transfer_in_received & transfer_in_received_reg)
            transfer_in_received_reg <= 1'b0;
    end
end
```

4.11 USB Transfer State Machine

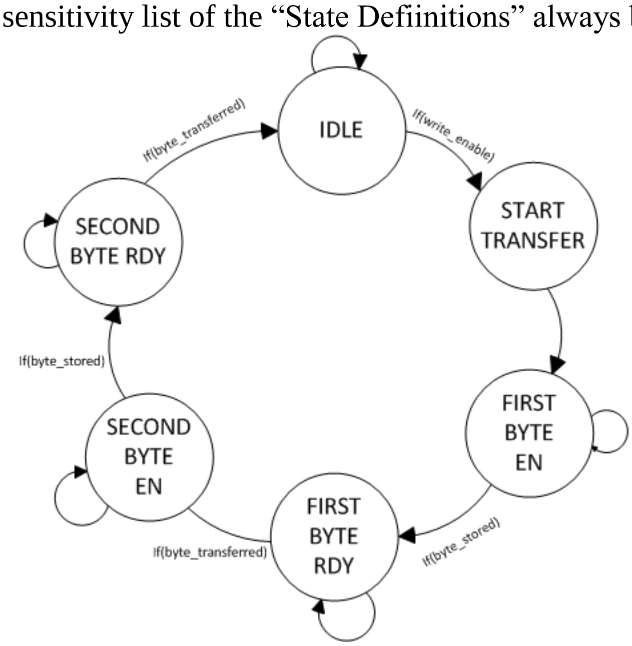
The USB Transfer State Machine is quite a bit different than the Transfer Control state machine. It is two always statement one-hot finite state machine. It is used here because it provides high speed glitch free operation. One hot means that it has one register for each state. The two always block setup allows a synchronous operation to be relegated to moving the state machine to the next state.

```
// Next State Logic
always @(posedge CLK_66 or negedge RST)
 begin
if (!RST)
  begin
     state <= 6'h000;
     state[IDLE] <= 1'b1;
  end
else
  state <= next;
 end
```

An asynchronous always block is used to select which state will be the next state. All of the outputs are handled in their own always blocks and separate from the state machine.

```
  // State Definitions
always @ ( state or transfer_write or first_byte_complete or
           second_byte_complete or transfer_write or start_transfer_array or
           transfer_busy_array)
  begin
  next = 6'h000;
```

This asynchronous always block is the one which causes the state machines conditional branches to update. If the conditional branches are not updated with the correct inputs, then the next[…] statement will not get updated with the correct state and the state machine could get stuck in the wrong state. So, each input into the state machine MUST be entered into the sensitivity list of the “State Defiinitions” always block.



1. The state machine stays in state[IDLE] until the analog_monitor_en goes high. When this signal goes high, the state machine goes into

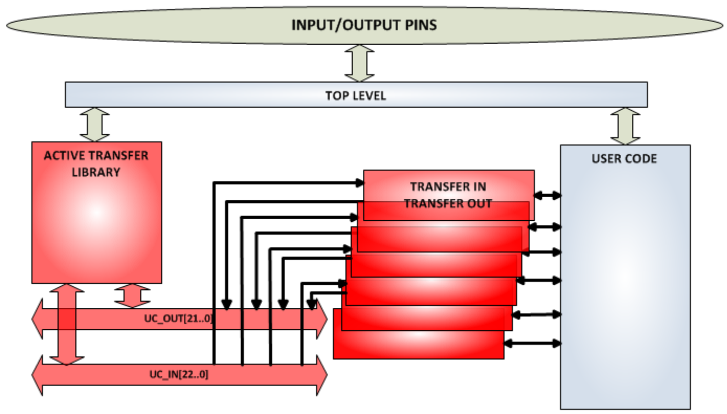
state[START_TRANSFER]. This state causes the transfer_out to latch an EndTerm selection based on the transfer_address. This state does not have a conditional branch, so it immediately proceeds to state[FIRST_BYTE_EN].

2. In state[FIRST_BYTE_EN], the “Transfer Upper/Lower byte using selected Active Transfer EndTerm” block will select the upper byte to transfer over the USB. A conditional branch causes the state machine to stay in this state until first_byte_complete goes high.
3. The next state is state[FIRST_BYTE_RDY]. Here the byte has been transferred into the Active Transfer EndTerm selected by start_transfer_array. This state has a conditional branch that waits until the byte has been transferred across the USB and the Active Transfer Library is ready. It waits for transfer_busy_array to be zero.
4. The state machine progresses to state[SECOND_BYTE_EN] and causes the “Transfer Upper/Lower byte using selected Active Transfer EndTerm” block to select the lower byte to transfer over the USB. A conditional branch causes the state machine to stay in this state until second_byte_complete goes high. Upon its assertion, the state machine proceeds to state[SECOND_BYTE_RDY].
5. In state[SECOND_BYTE_RDY] the byte has been transferred into the Active Transfer EndTerm selected by start_transfer_array. This state has a conditional branch that waits until the byte has been transferred across the USB and the Active Transfer Library is ready. It waits for transfer_busy_array to be zero.
6. Upon successful completion of the second byte transfer, the state machine goes back to the state[IDLE] and waits for analog_monitor_en to go high and start the process over again.

```
if (state[IDLE])
  begin
     if (transfer_write)
       next[START_TRANSFER] = 1'b1;
     else
       next[IDLE] = 1'b1;
  end

if (state[START_TRANSFER])
        next[FIRST_BYTE_EN] = 1'b1;

if (state[FIRST_BYTE_EN])
    if ( first_byte_complete )
        next[FIRST_BYTE_RDY] = 1'b1;
    else
        next[FIRST_BYTE_EN] = 1'b1;

if (state[FIRST_BYTE_RDY])
    if ( transfer_busy_array == 0)
        next[SECOND_BYTE_EN] = 1'b1;
    else
        next[FIRST_BYTE_RDY] = 1'b1;

if (state[SECOND_BYTE_EN])
    if ( second_byte_complete )
        next[SECOND_BYTE_RDY] = 1'b1;
    else
        next[SECOND_BYTE_EN] = 1'b1;

if (state[SECOND_BYTE_RDY])
    if ( transfer_busy_array == 0)
        next[IDLE] = 1'b1;
    else
        next[SECOND_BYTE_RDY] = 1'b1;
```

4.12 EndTerm Instantiation

Next, up is the instantiation for the active_transfer_library. The ports include the input and output pins and the two buses that connect the active modules. These buses are the input UC_IN[23:0] and output UC_OUT[21:0].




```
//-----------------------------------------------
// Instantiate the EPT Active Transfer Library
//-----------------------------------------------

active_transfer_library    ACTIVE_TRANSFER_LIBRARY_INST
(
.aa                         (aa),
.bc_in                      (bc_in),
.bc_out                     (bc_out),
.bd_inout                   (bd_inout),

.UC_IN                      (UC_IN),
.UC_OUT                     (UC_OUT)

);
```

Finally, we instantiate the EndTerms. For the Analog Monitor project, we only need active_transfer and active_trigger EndTerms. The uc_out port for both modules must be shared. Since they both drive this bus, a bus wide wired-or circuit is used so that they don't drive each other. The active_transfer EndTerm has a port for the address (uc_addr). This allows the PC to address up to 8 different modules. Just add a three bit address to this port and the PC must add this same address to communicate with this module.

```
    //-----------------------------------------------
    // Instantiate the EPT Active Modules
    //-----------------------------------------------
wire [22*6-1:0]  uc_out_m;
eptWireOR # (.N(6)) wireOR (UC_OUT, uc_out_m);
```

Next, we will instantiate six Active Transfer EndTerms. So, add the leaf instantiation with the address fixed 1, 2, 3, 4, 5, 6, for each EndTerm. Add the start_transfer_array, transfer_busy_array and transf_out_byte to control the transmission of the digitized value across the USB.

```
active_transfer               ACTIVE_TRANSFER_INST_1
(
 .uc_clk                      (CLK_66),
 .uc_reset                    (RST),
 .uc_in                       (UC_IN),
 .uc_out                      (uc_out_m[ 1*22 +: 22 ]),

 .start_transfer              (start_transfer_array[0]),
 .transfer_received           (),

 .transfer_busy               (transfer_busy_array[0]),

 .uc_addr                     (3'h1),

 .transfer_to_host            (transfer_out_byte),
 .transfer_to_device          ()
);


active_transfer               ACTIVE_TRANSFER_INST_2
(
 .uc_clk                      (CLK_66),
 .uc_reset                    (RST),
 .uc_in                       (UC_IN),
 .uc_out                      (uc_out_m[ 2*22 +: 22 ]),

 .start_transfer              (start_transfer_array[1]),
 .transfer_received           (transfer_in_received),

 .transfer_busy               (transfer_busy_array[1]),

 .uc_addr                     (3'h2),

 .transfer_to_host            (transfer_out_byte),
 .transfer_to_device          (transfer_in_byte)
);
```

```
active_transfer                ACTIVE_TRANSFER_INST_3
(
 .uc_clk                       (CLK_66),
 .uc_reset                     (RST),
 .uc_in                        (UC_IN),
 .uc_out                       (uc_out_m[ 3*22 +: 22 ]),

 .start_transfer               (start_transfer_array[2]),
 .transfer_received            (),

 .transfer_busy                (transfer_busy_array[2]),

 .uc_addr                      (3'h3),

 .transfer_to_host             (transfer_out_byte),
 .transfer_to_device           ()
);

active_transfer                ACTIVE_TRANSFER_INST_4
(
 .uc_clk                       (CLK_66),
 .uc_reset                     (RST),
 .uc_in                        (UC_IN),
 .uc_out                       (uc_out_m[ 4*22 +: 22 ]),

 .start_transfer               (start_transfer_array[3]),
 .transfer_received            (),

 .transfer_busy                (transfer_busy_array[3]),

 .uc_addr                      (3'h4),

 .transfer_to_host             (transfer_out_byte),
 .transfer_to_device           ()
 );
```

```
active_transfer                 ACTIVE_TRANSFER_INST_5
(
 .uc_clk                        (CLK_66),
 .uc_reset                      (RST),
 .uc_in                         (UC_IN),
 .uc_out                        (uc_out_m[ 5*22 +: 22 ]),

 .start_transfer                (start_transfer_array[4]),
 .transfer_received             (),

 .transfer_busy                 (transfer_busy_array[4]),

 .uc_addr                       (3'h5),

 .transfer_to_host              (transfer_out_byte),
 .transfer_to_device            ()
);

active_transfer                 ACTIVE_TRANSFER_INST_6
(
 .uc_clk                        (CLK_66),
 .uc_reset                      (RST),
 .uc_in                         (UC_IN),
 .uc_out                        (uc_out_m[ 6*22 +: 22 ]),

 .start_transfer                (start_transfer_array[5]),
 .transfer_received             (),

 .transfer_busy                 (transfer_busy_array[5]),

 .uc_addr                       (3'h6),

 .transfer_to_host              (transfer_out_byte),
 .transfer_to_device            ()
);


endmodule
```

The “endmodule” signifies the module is done and no more code is allowed beyond that point.

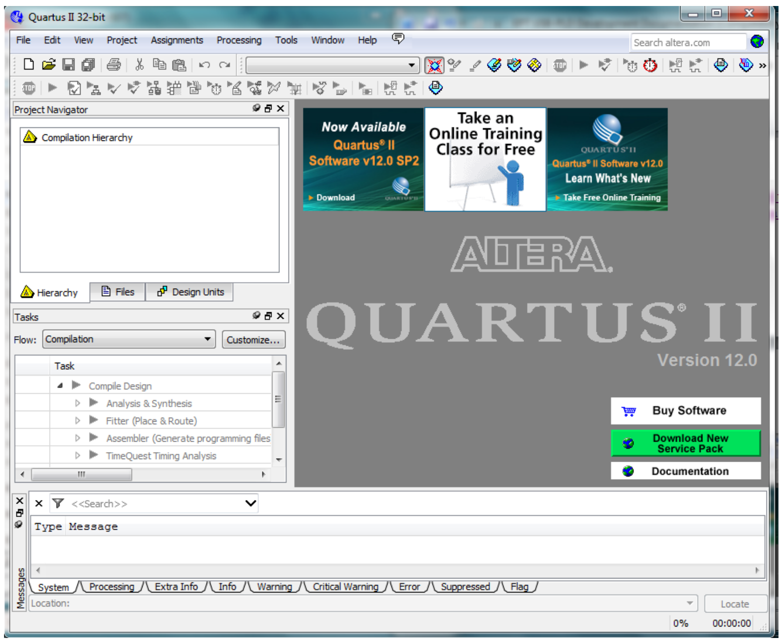
Next, we are ready to compile and synthesize.

4.13 Compile/Synthesize the Project

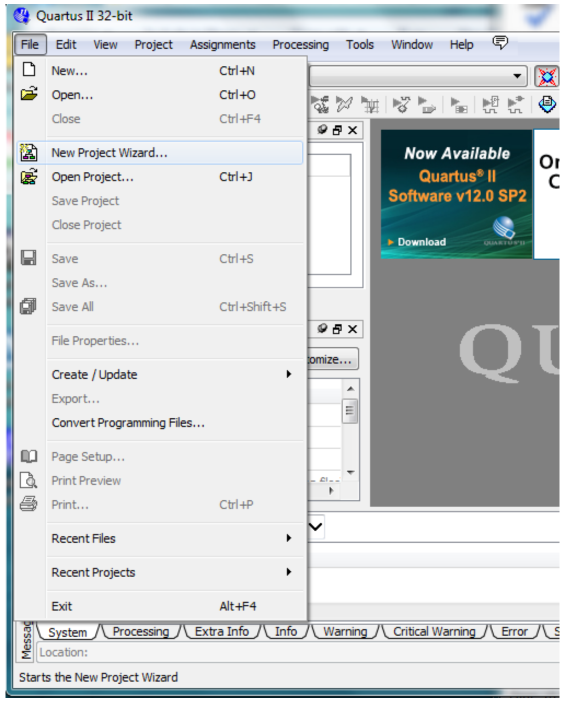
The Quartus II application will compile/ synthesize the user code, active_transfer_library, and the Active EndTerms. The result of this step is a file containing the CPLD code with “*.pof”. First, we need to create a project in the Quartus II environment. Follow the directions in the section: “Compiling, Synthesizing, and Programming CPLD” of the User Manual.

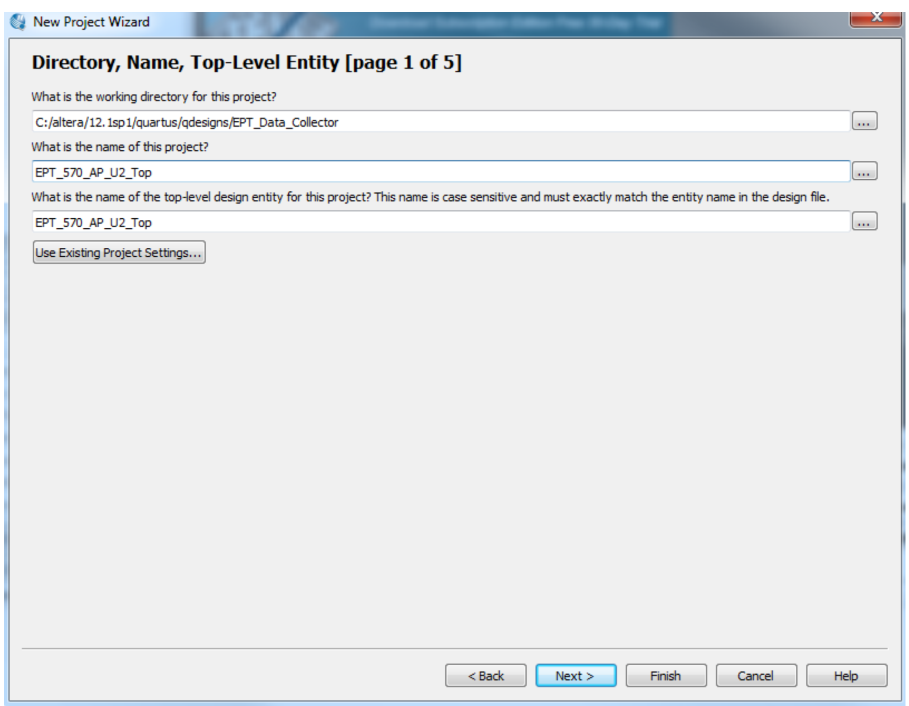
Bring up Quartus II, then use Windows Explorer to browse to c:/altera/xxx/quartus/qdesigns create a new directory called: “EPT_Analog_Monitor”.

Open Quartus II by clicking on the icon . 



Under Quartus, Select File->New Project Wizard. The Wizard will walk you through setting up files and directories for your project.


Quartus II 32-bit
File
Edit
View
Project
Assignments
Processing
Tools
Window
Help
New... Ctrl+N
Open... Ctrl+O
Close Ctrl+F4
New Project Wizard...
Open Project... Ctrl+J
Save Project
Close Project
Save Ctrl+S
Save As...
Save All Ctrl+Shift+S
File Properties...
Create / Update
Export...
Convert Programming Files...
Page Setup...
Print Preview
Print... Ctrl+P
Recent Files
Recent Projects
Exit Alt+F4
Now Available
Quartus® II
Software v12.0 SP2
Download
System
Processing
Extra Info
Info
Warning
Critical Warning
Error
Location:
Starts the New Project Wizard

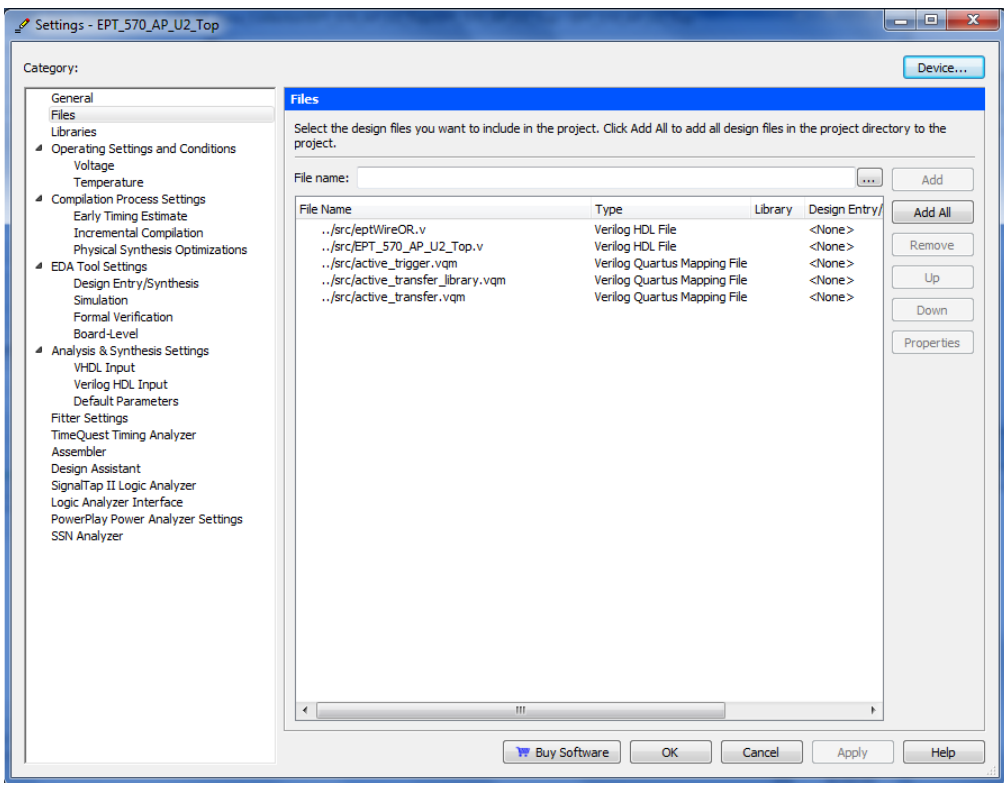

New Project Wizard
Directory, Name, Top-Level Entity [page 1 of 5]
What is the working directory for this project?
C:/altera/12.1sp1/quartus/qdesigns/EPT_Data_Collector
What is the name of this project?
EPT_570_AP_U2_Top
What is the name of the top-level design entity for this project? This name is case sensitive and must exactly match the entity name in the design file.
EPT_570_AP_U2_Top
Use Existing Project Settings...
< Back
Next >
Finish
Cancel
Help

At the Top-Level Entity page, browse to the c:\altera\xxx\quartus\qdesigns\EPT_Analog_Monitor directory to store your project. Type in a name for your project "EPT_570_AP_U2_Top".

Follow the steps up to Add Files. At the Add Files box, click on the Browse button and navigate to the project Analog Monitor install folder in the dialog box. Browse to the \Projects_HDL\EPT_ Analog_Monitor \EPT_570_AP_U2_Top folder of the EPT USB-CPLD Development System CD. Copy the files from the \src directory.

- Active_transfer.vqm
- Active_trigger.vqm
- Active_transfer_library.vqm
- eptWireOr.v
- ETP_570_AP_U2_Top.v

Add the files:



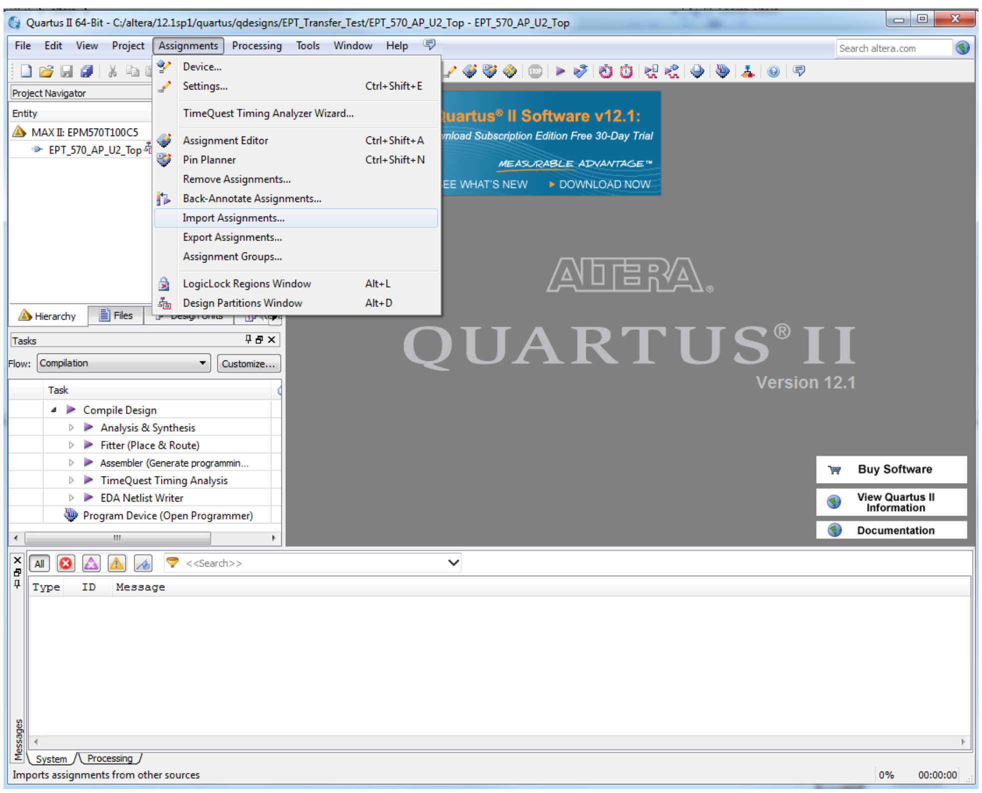
Select Next, at the Device Family group, select MAX II for Family. In the Available Devices group, browse down to EPM570T100C5 for Name.

Select Next, leave defaults for the EDA Tool Settings.

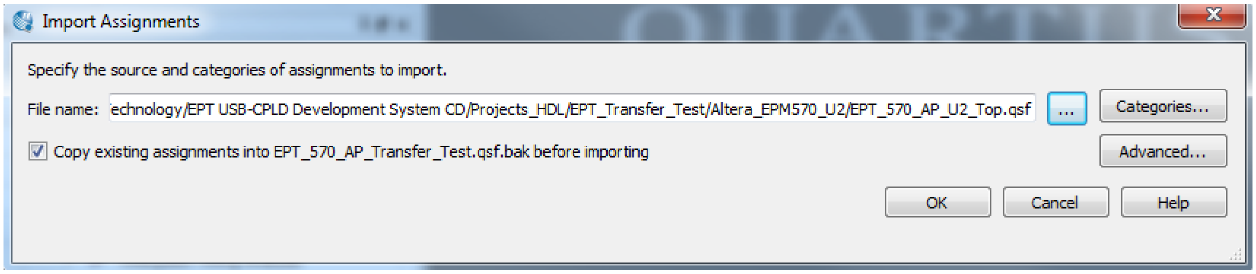
Select Next, then select Finish. You are done with the project level selections.

4.14 Synthesizing

With the project created, we need to assign pins to the project. The signals defined in the top level file (in this case: EPT_570_AP_U2_Top.v) will connect directly to pins on the CPLD. The Pin Planner Tool from Quartus II will add the pins and check to verify that our pin selections do not violate any restrictions of the device. In the case of this example we will import pin assignments that created at an earlier time. Under Assignments, Select Import Assignments.



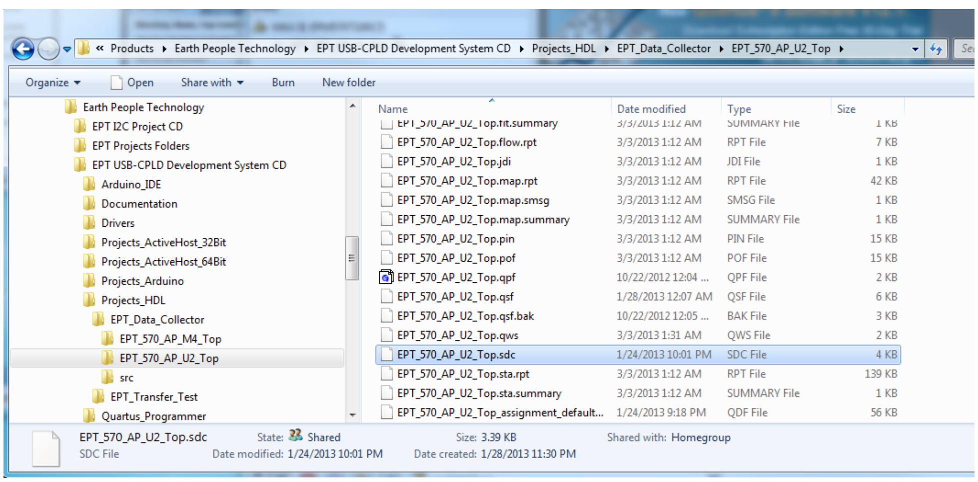
At the Import Assignment dialog box, Browse to the \Projects_HDL\EPT_Transfer_Test \Altera_EPM570_U2 folder of the EPT ANALOG_MONITOR_PROJECT CD. Select the “EPT_570_AP_U2_Top.qsf” file.



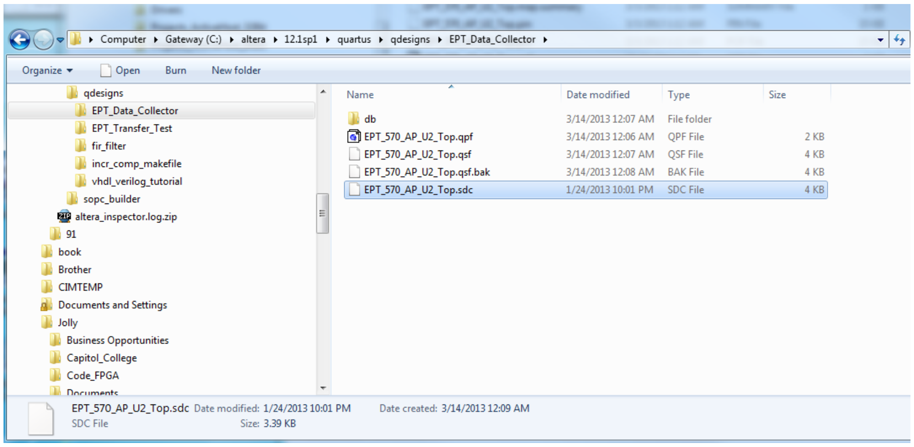
Next, we need to add the Synopsys Design Constraint file. This file contains timing constraints which forces the built in tool called TimeQuest Timing Analyzer to analyze the path of the synthesized HDL code with setup and hold times of the internal registers. It takes note of any path that may be too long to appropriately meet the timing qualifications. For more information on TimeQuest Timing Analyzer, see

http://www.altera.com/literature/hb/qts/qts_qii53018.pdf?GSA_pos=1&WT.oss_r=1&WT.oss=TimeQuest Timing Analyzer

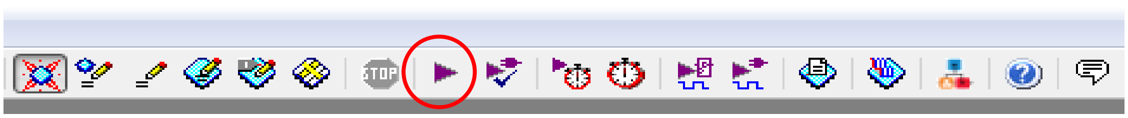
Browse to the \Projects_HDL\EPT_ Analog_Monitor \Altera_EPM570_U2 folder of the EPT USB-CPLD Development System CD. Select the “EPT_570_AP_U2_Top.sdc” file.



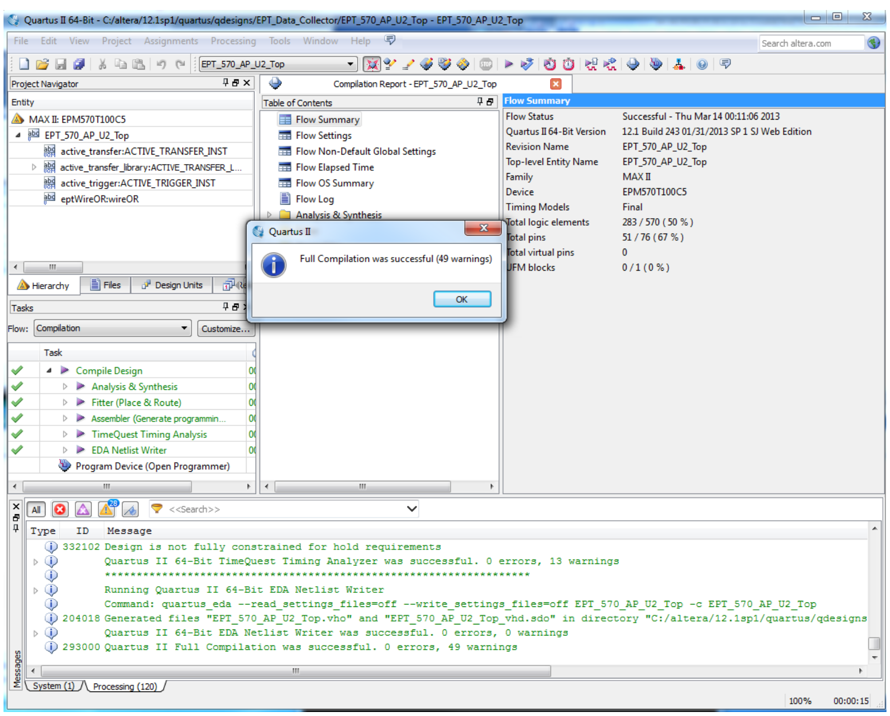
Copy the file and browse to c:\altera\xxx\quartus\qdesigns\EPT_Analog_Monitor directory. Paste the file.



and select the Start Compilation button.



This will cause the compile and synthesization process. After successful completion, the screen should look like the following:



If the synthesis fails, you will see the failure message in the message window. Note that in addition to fatal errors, the compile process can produce "warnings" which do not necessarily prevent execution of the code but which should be corrected eventually.

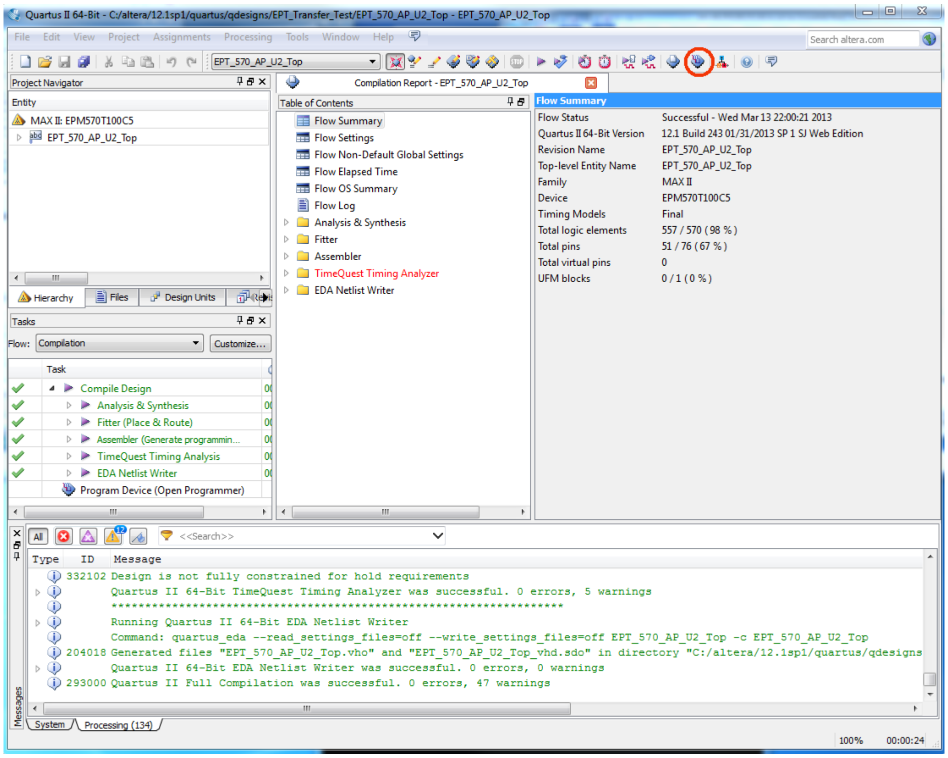
At this point the project has been successfully compiled, synthesized and a programming file has been produced. See the next section on how to program the CPLD.

4.15 Program the CPLD

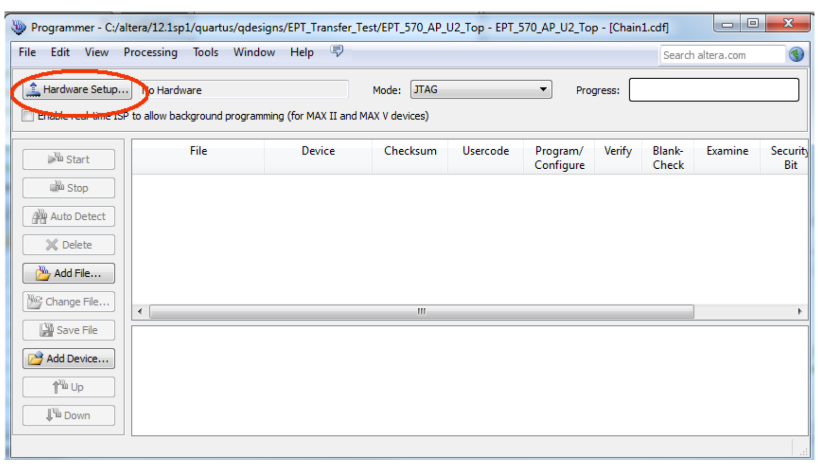
The final step is programming the "*.pof" file into the CPLD.

- Connect the EPT-570-AP to the PC,
- Open up Quartus II,
- Open the programmer tool

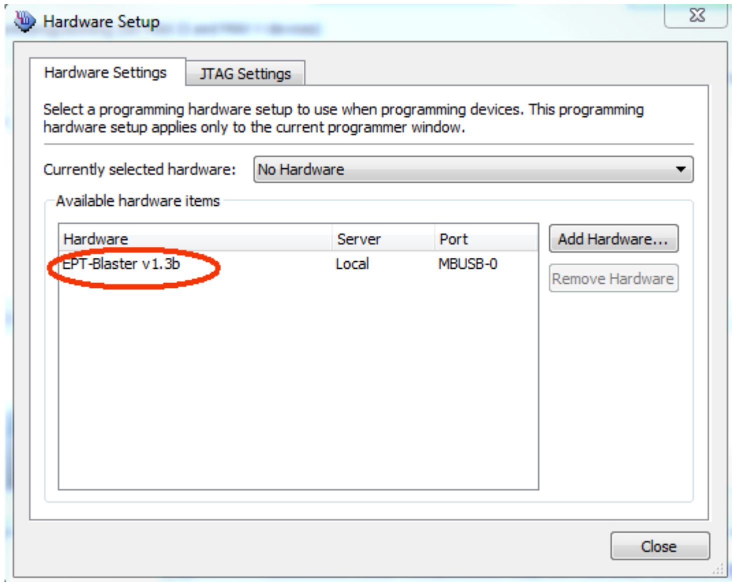
If the project created in the previous sections is not open, open it. Click on the Programmer button.



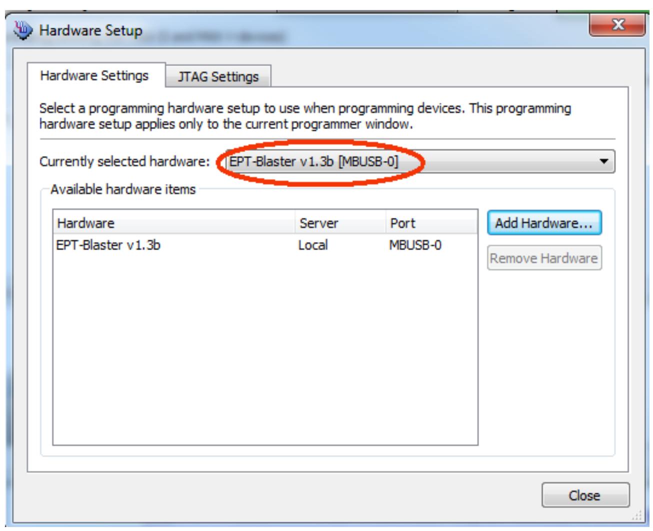
The Programmer Window will open up with the programming file selected. Click on the Hardware Setup button in the upper left corner.



The Hardware Setup Window will open. In the “Available hardware items”, double click on “EPT-Blaster v1.3b”.

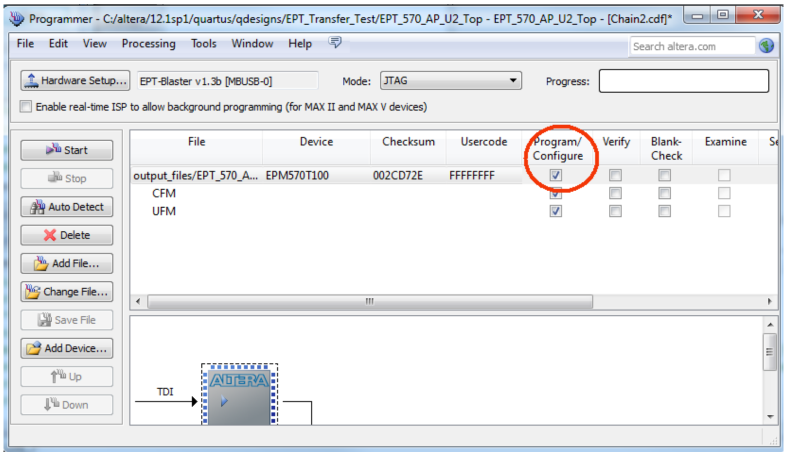


If you successfully double clicked, the "Currently selected hardware:" dropdown box will show the "EPT-Blaster v1.3b".

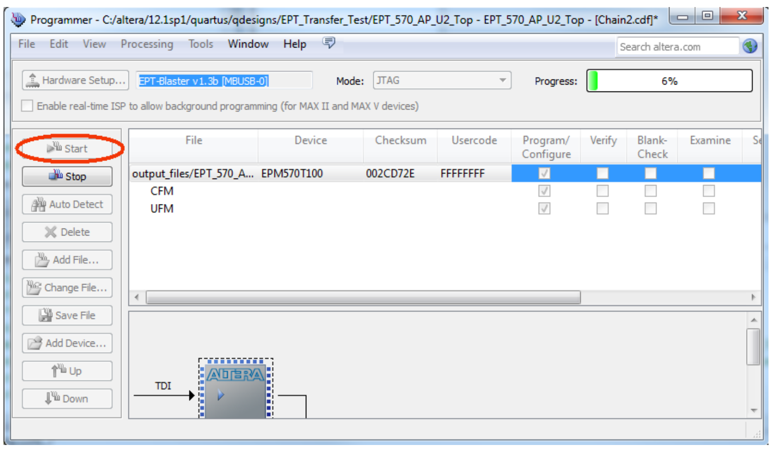


Click the "Close" button.

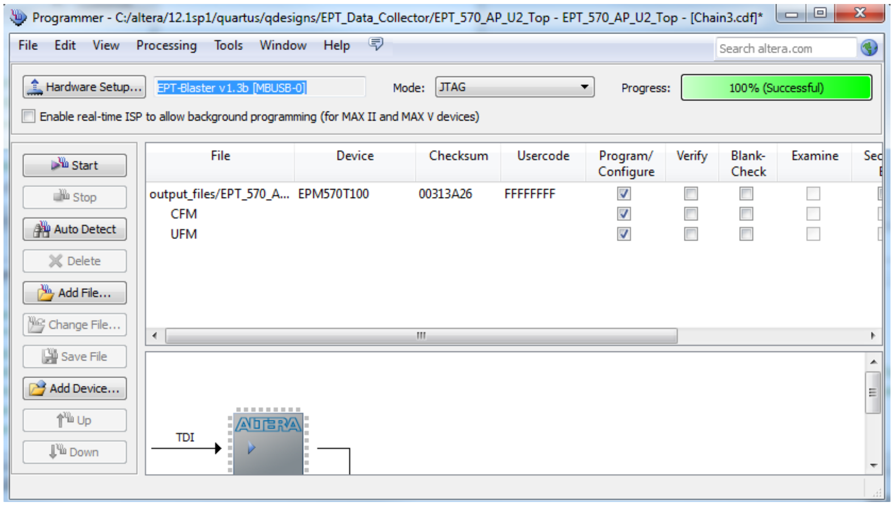
Next, selet the checkbox under the "Program/Configure" of the Programmer Tool. The checkboxes for the CFM and UFM will be selected automatically.



Click on the Start button to to start programming the CPLD. The Progress bar will indicate the progress of programming.



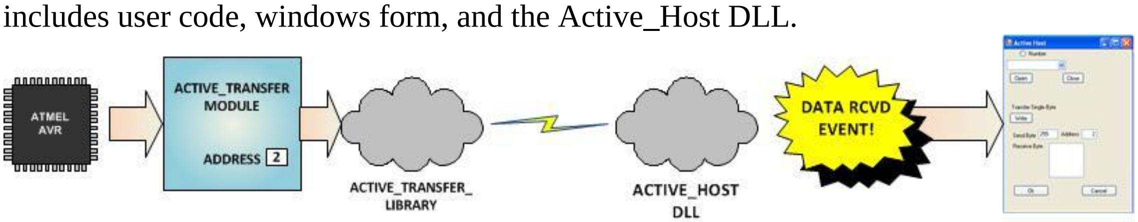
When the programming is complete, the Progress bar will indicate success.



At this point, the EPT-570-AP is programmed and ready for use.

5 PC: C# Project Design

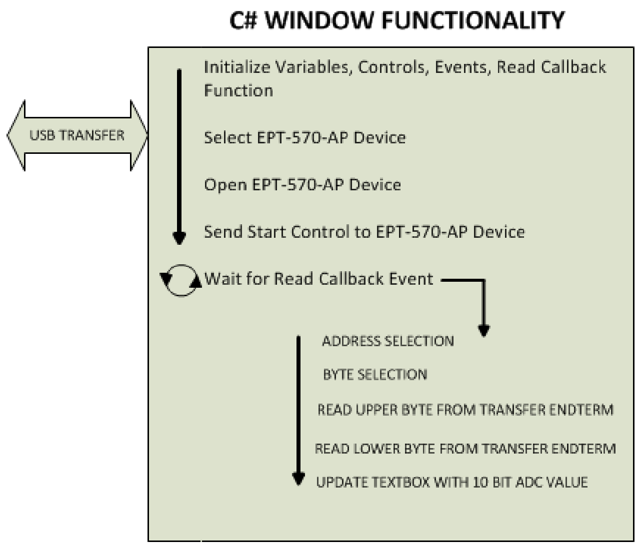
The final piece of the Analog Monitor Project is the PC application. This application will fetch the data from the CPLD of the EPT-570-AP and display it on the screen. It includes user code, windows form, and the Active_Host DLL.



The Active_Host DLL is designed to transfer data from the CPLD when it becomes available. The data will be stored into local memory of the PC, and an event will be triggered to inform the user code that data is available from the addressed module of the CPLD. This method, from the user code on the PC, makes the data transfer transparent. The data just appears in memory and the user code will direct the data to a textbox on the Windows Form.

The Analog Monitor project will perform the following functions.

- Find EPT-570-AP Device.
- Open EPT-570-AP Device.
- Start the Arduino data collection process.
- Wait for data from EPT-570-AP.
- Decode byte position, upper or lower.
- Display data from EPT-570-AP in textbox.



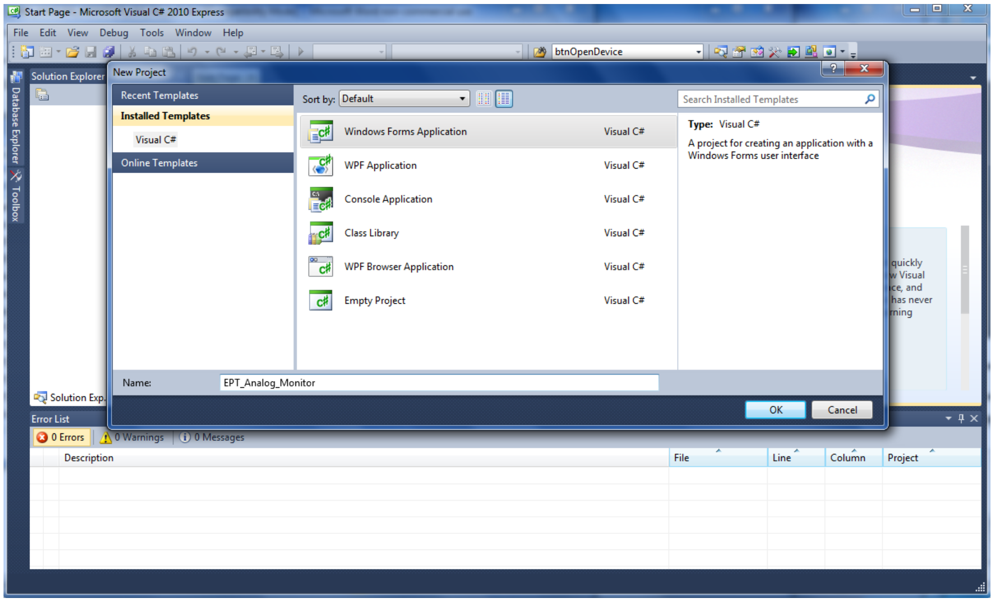
5.1 Coding the C# Project

The user code is based on the .NET Framework and written in C#. The language is great for beginners as it is a subset of the C++ language. It has the look and feel of the familiar C language but adds the ease of use of classes, inheritance and method overloading. C# is an event based language which changes the method of writing code for this project. You will need to get some background knowledge in coding with C# and the .NET Framework on the PC. For a better description of event based language programming and C#, see the following for a turtorial

http://www.homeandlearn.co.uk/csharp/csharp.html

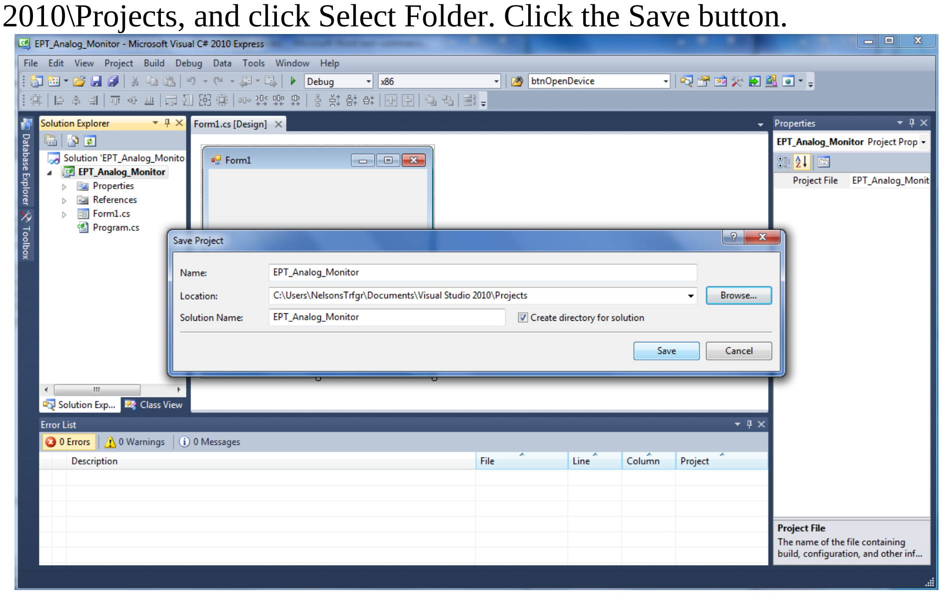
5.1.1 C# Project Creation

To start the project, use the wizard to create project called "EPT_Analog_Monitor". When the wizard completes, the C# Express main window will look like the following.



The setup statements create the namespace and the class for the project. There are several other files that are created by the wizard such as Form1.Designer.cs, Program.cs, Form1.resx. We don't need to go into these support files, we will just focus on the Form1.cs as this is where all the user code goes.

Click on File->Save Project as. Browse to C:\Users\<user name>\Documents\Visual Studio 2010\Projects, and click Select Folder. Click the Save button.

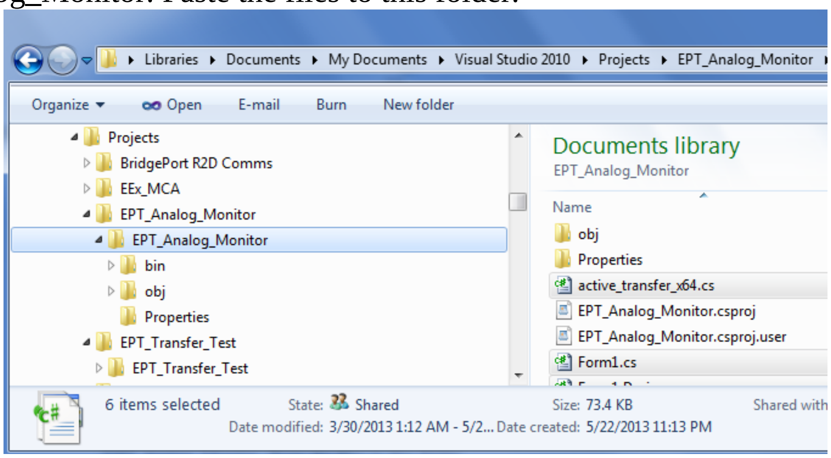


Locate the \Projects_ActiveHost_64Bit\EPT_Analog_Monitor\ folder in the UNO_ANALOG_MONITOR_PROJECT_CD. Copy the following files:

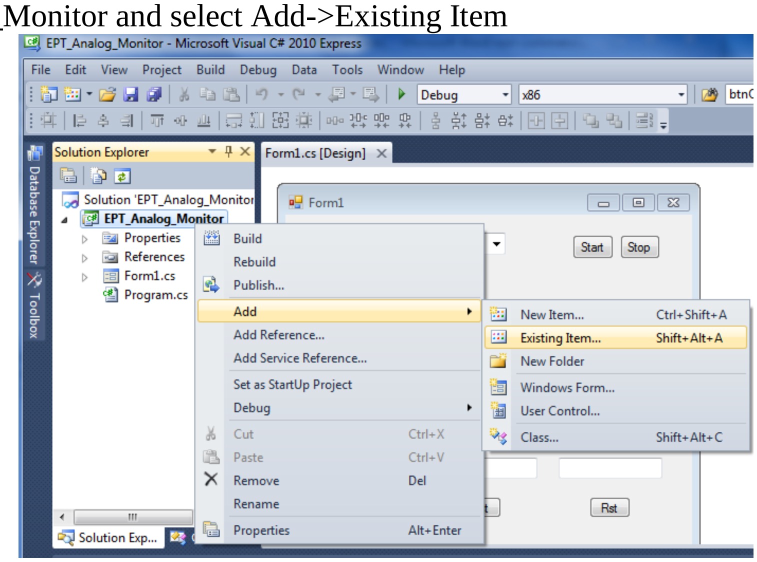
- active_transfer_x64.cs
- Form1.cs

- Form1.Designer.cs
- Form1.resx
- Program.cs
- ScaleFactorMenu.cs

Open a Windows Explorer window and browse to C:\Users\NelsonsTrfgr\Documents\Visual Studio 2010 \Projects \EPT_Analog_Monitor \EPT_Analog_Monitor. Paste the files to this folder.

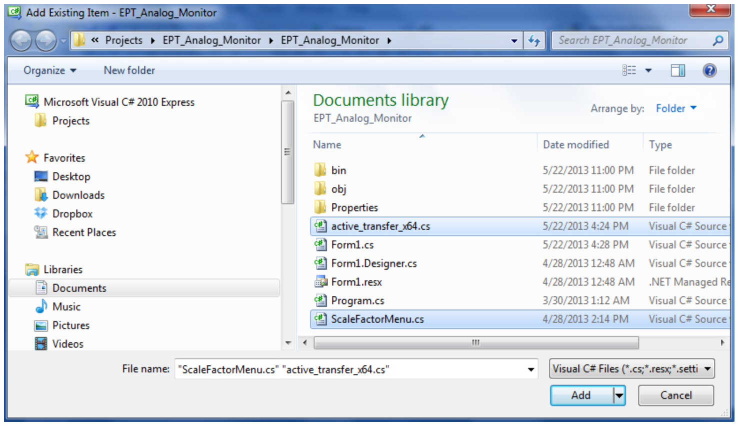


In the Solution Explorer Window, right click on the project name, EPT_Analog_Monitor and select Add->Existing Item



Select the following files:

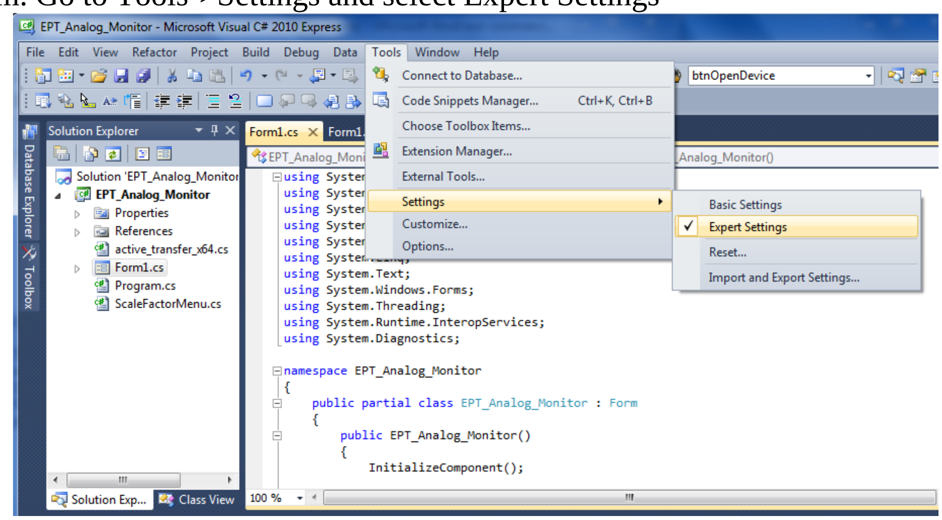
- active_transfer_x64.cs
- ScaleFactorMenu.cs



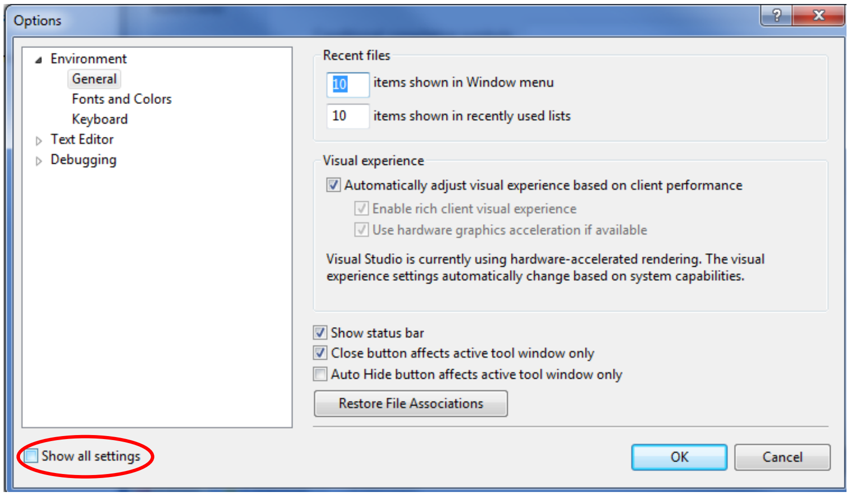
Click Add.

5.1.2 C# Project Environment Setup

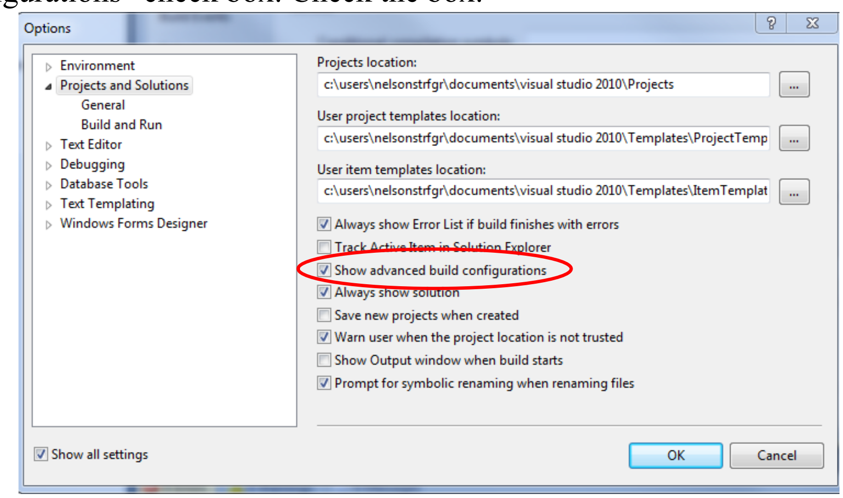
The project environment must be set up correctly in order to produce an application that runs correctly on the target platform. Visual C# Express defaults new projects to 32 bits. If your OS is a 64 bit platform, use the following directions to set up a 64 bit project. First, we need tell C# Express to produce 64 bit code if we are running on a x64 platform. Go to Tools->Settings and select Expert Settings



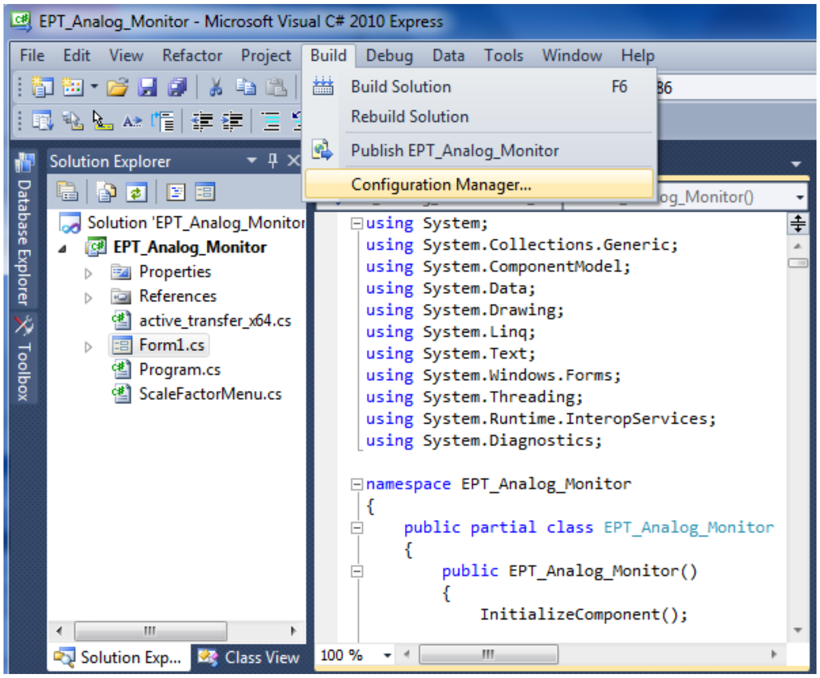
Go to Tools->Options, locate the “Show all settings” check box. Check the box.



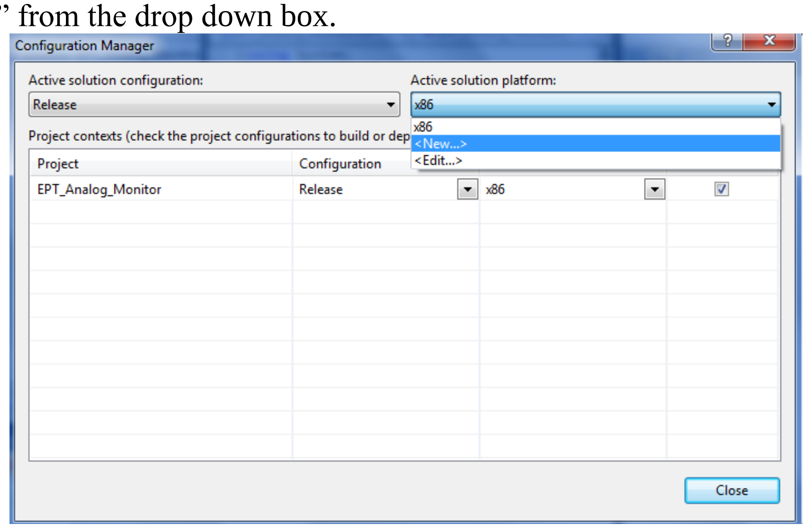
In the window on the left, go to “Projects and Solutions”. Locate the “Show advanced build configurations” check box. Check the box.



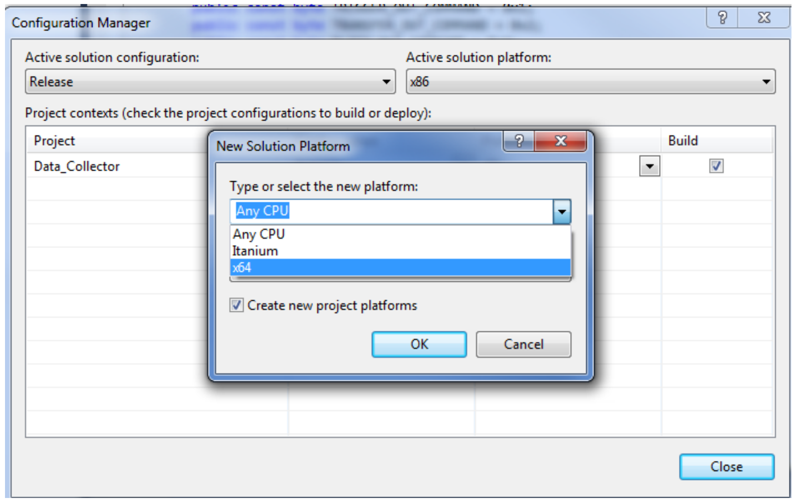
Go to Build->Configuration Manager.



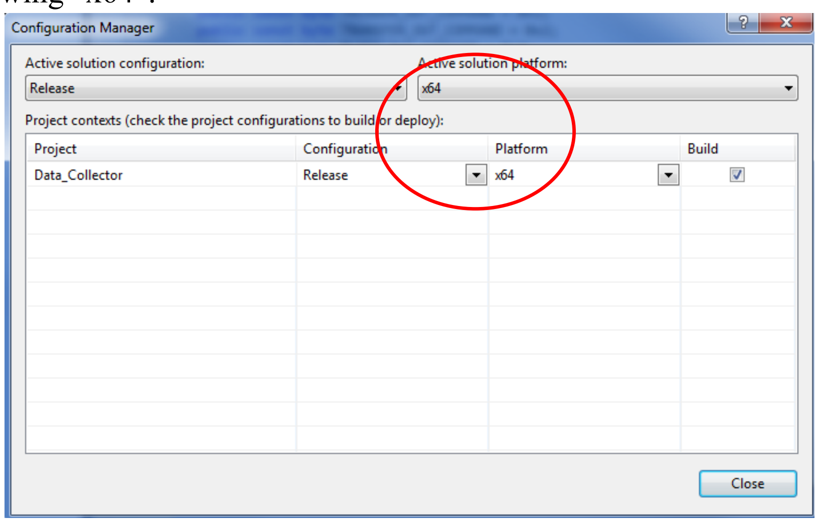
In the Configuration Manager window, locate the “Active solution platform:” label, select “New” from the drop down box.



In the New Solution Platform window, click on the drop down box under “Type or select the new platform:” and select “x64”.

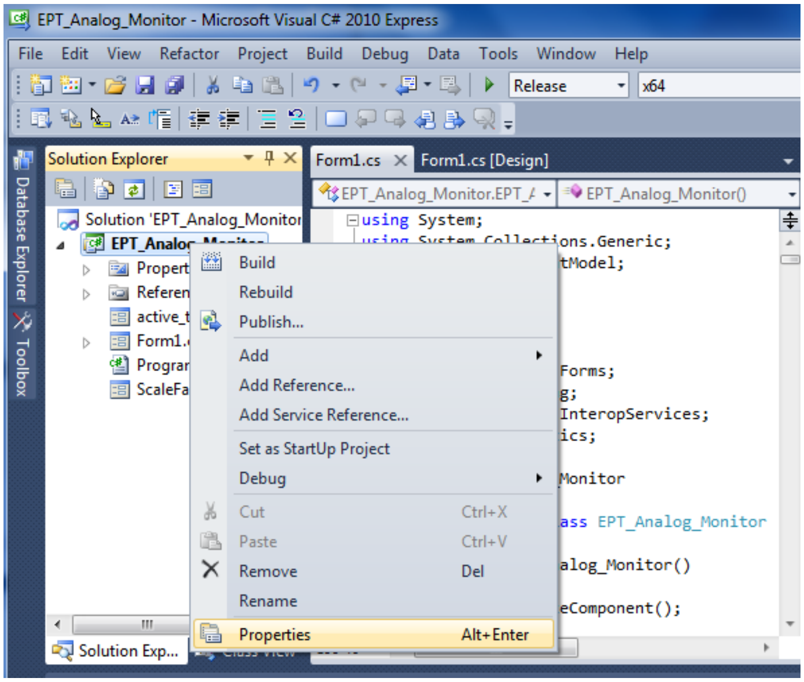


Click the Ok button. Verify that the "Active Solution Platform" and the "Platform" tab are both showing "x64".

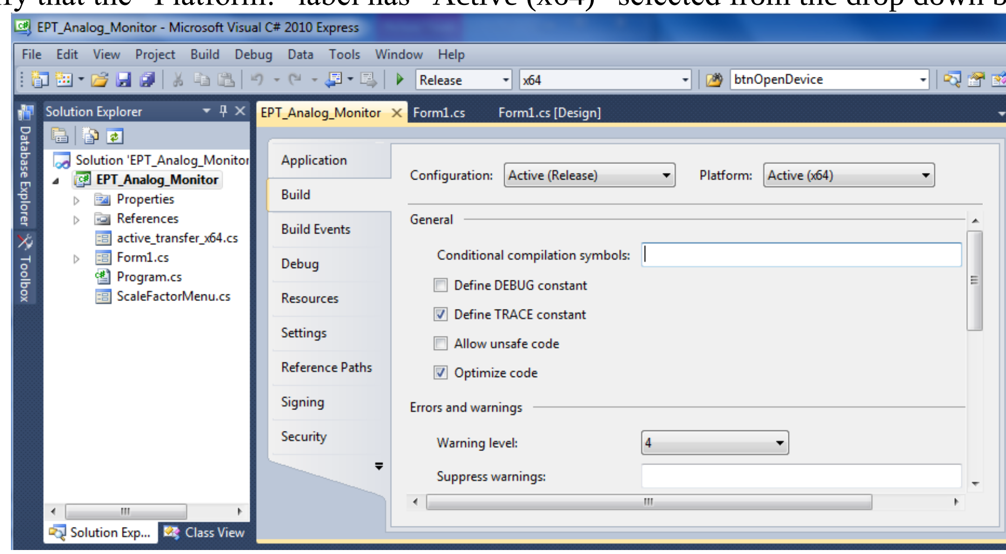


Click Close.

Then, using the Solution Explorer, you can right click on the project, select Properties and click on the Build tab on the right of the properties window.

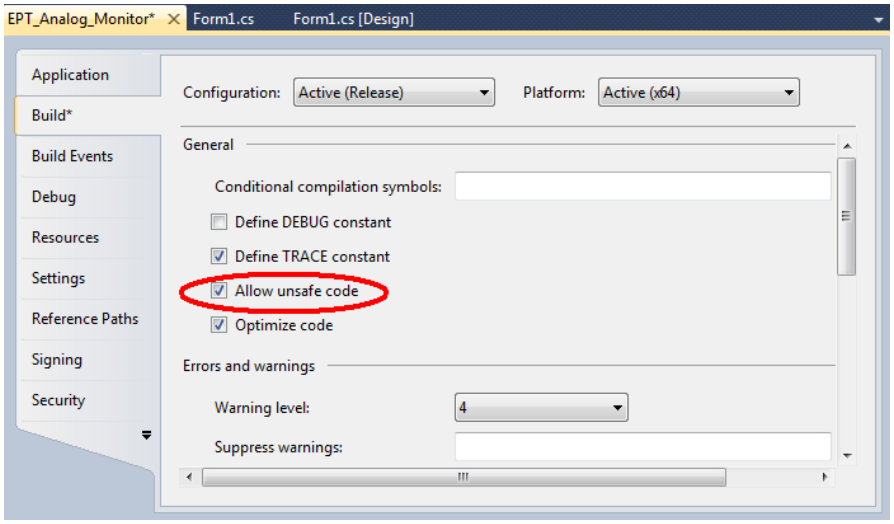


Verify that the “Platform:” label has “Active (x64)” selected from the drop down box.



Next, unsafe code needs to be allowed so that C# can be passed pointer values from the Active Host.

Locate the “Allow unsafe code” check box. Check the box



5.1.3 C# Object Initialization

Now we are ready to start coding.

Next, we add two classes for our device. One class stores the information useful for our device for Transmit to the EndTerms such as, address of module, length of transfer etc.

```
//Create an array of the Transfer Class for device
Transfer[] EPTTransmitDevice = new Transfer[8];
```

The next class is used to store parameters for receiving data from the device.

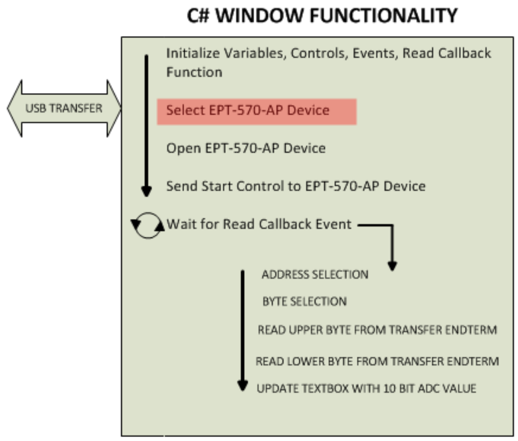
```
//Create a Receive object of the Transfer Class.
Transfer EPTReceiveData = new Transfer();
```

The first function called when the Windows Form loads up is the EPT_Analog_Monitor _Load(). This function is called automatically upon the completion of the Windows Form, so there is no need to do anything to call it. Once this function is called, it in turn calls the ListDevices().

```
// Main object loader
private void EPT_Analog_Monitor_Load(object sender, System.EventArgs e)
{
    // Call the List Devices function
    ListDevices();
}
```

5.1.4 C# Project ListDevices

The ListDevices() function calls the EPT_AH_Open() function to load up the

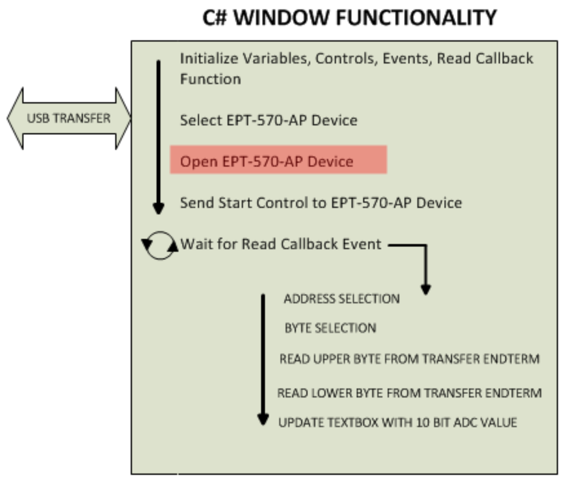


ActiveHost Dll. Next, it calls EPT_AH_QueryDevices() which searches through the registry files to determine the number of EPT devices attached to the PC. Next, EPT_AH_GetDeviceName() is called inside a for loop to return the ASCII name of each device attached to the PC. It will automatically populate the combo box, cmbDevList with all the EPT devices it finds.

```
// List Devices function
private unsafe Int32 ListDevices ()
   {
   Int32 result;
   Int32 num_devices;
   Int32 iCurrentIndex;

   // Open the DLL
   result = EPT_AH_Open(null, null, null);
   if (result != 0)
      {
      MessageBox.Show("Could not attach to the ActiveHost library");
      return 0;
      }

   // Query connected devices
   num_devices = EPT_AH_QueryDevices();

   //Prepare the Combo box for population
   iCurrentIndex = cmbDevList.SelectedIndex;
   cmbDevList.Items.Clear();

   // Go through all available devices
   for (device_index = 0; device_index < num_devices; device_index++)
      {
          String str;
          str = Marshal.PtrToStringAnsi((IntPtr)EPT_AH_GetDeviceName(device_index));
          cmbDevList.Items.Add(str);
      }
   return 0;
}
```

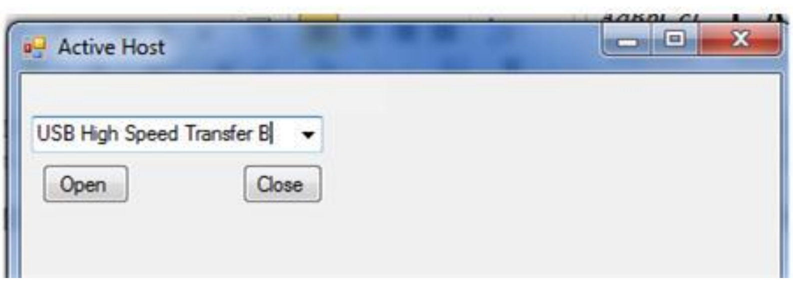
5.1.5 C# Project Open Device

The user will select the device from the drop down combo box. This value can be sent



to the OpenDevice() function using the button Click of the Open button.

```
// Open the device
if (EPT_AH_OpenDeviceByIndex(device_index) == false)
    {
    printf("Could not open device %s\n", EPT_AH_GetDeviceName(device_index));
    exit(0);
    }
```



The device_index variable is used to store the index of the device selected from the combo box. This variable is passed into the EPT_AH_OpenDeviceByIndex(). This process is started by the user clicking on the “Open” button. If the function is successful, the device name is displayed in the label, labelDeviceCnt. Next, the device is made the active device and the call back function is registered using the RegisterCallBack() function. Finally, the Open button is grayed out and the Close button is made active.

```
    // Open the device
public unsafe Int32 OpenDevice()
{
    device_index = (int)cmbDevList.SelectedIndex;
    if (EPT_AH_OpenDeviceByIndex(device_index) == 0)
    {
        String message = "Could not open device " +
            Marshal.PtrToStringAnsi((IntPtr)EPT_AH_GetDeviceName(device_index)) + ", " +
            Marshal.PtrToStringAnsi((IntPtr)EPT_AH_GetDeviceSerial(device_index));
        MessageBox.Show(message);
        return 0;
    }
    else
    {
        labelDeviceCnt.Text = "Connected to device " +
            Marshal.PtrToStringAnsi((IntPtr)EPT_AH_GetDeviceName(device_index)) + ", " +
            Marshal.PtrToStringAnsi((IntPtr)EPT_AH_GetDeviceSerial(device_index));
    }

    // Make the opened device the active device
    if (EPT_AH_SelectActiveDeviceByIndex(device_index) == 0)
    {
        String message = "Error selecting device: %s " +
            Marshal.PtrToStringAnsi((IntPtr)EPT_AH_GetLastError());
        MessageBox.Show(message);
        return 0;
    }

    // Register the read callback function
    RegisterCallBack();
    btnOpenDevice.Enabled = false;
    btnCloseDevice.Enabled = true;
    return 0;
}
```

5.1.6 C# Project Callback Initialization

Next, the callback function is populated. This function will be called from the Active Host dll. When the EPT Device has transferred data to the PC, the callback function will do something with the data and command.

```
// Actual callback function which will read messages coming from the EPT device
unsafe void EPTReadFunction(Int32 device_id, Int32 device_channel, byte command, byte payload,
{
    byte* message = data;

    // Select current device
    EPT_AH_SelectActiveDeviceByIndex(device_id);

    //Add command and device_channel to the receive object
    EPTReceiveData.Command = ((command & COMMAND_DECODE) >> 3);
    EPTReceiveData.Address = device_channel;

    //Check if the command is Block Receive. If so,
    //use Marshalling to copy the buffer into the receive
    //object
    if (EPTReceiveData.Command == BLOCK_OUT_COMMAND)
    {
        EPTReceiveData.Length = data_size;
        EPTReceiveData.cBlockBuf = new Byte[data_size];

        Marshal.Copy(new IntPtr(message), EPTReceiveData.cBlockBuf, 0, data_size);
    }
    else
    {
        EPTReceiveData.Payload = payload;
    }
    EPTParseReceive();
}
```

Because the callback function communicates directly with the dll and must pass pointers from the dll to the C#, marshaling must be used. Marshaling is an advanced C# topic and will not be covered in this manual. We will let the callback function work in the background and we only need to use the EPTParseReceive() function to handle incoming data.

5.1.7 C# Project Controls

Controls such as buttons are added to the Form1.cs[Design] window which allow turning on and off signals. These include

- btnOk
- btnCancel
- btnOpenDevice
- btnCloseDevice
- btnStart
- btnStop
- btnSetScaleFactor
- btnResetBlock1 .. 6

Textboxes are used to display information on the Windows form. These textboxes are:

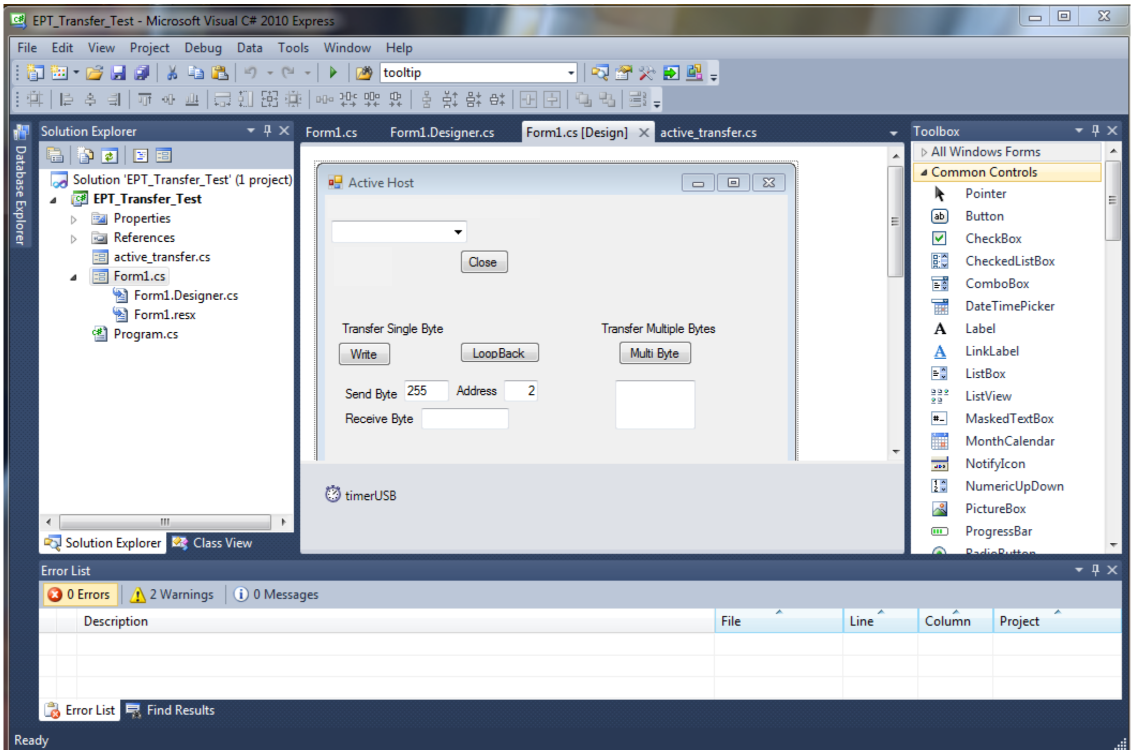
- cmbDevList
- tbMonitor1
- tbMonitor2
- tbMonitor3
- tbMonitor4
- tbMonitor5
- tbMonitor6

5.1.8 C# Project Buttons

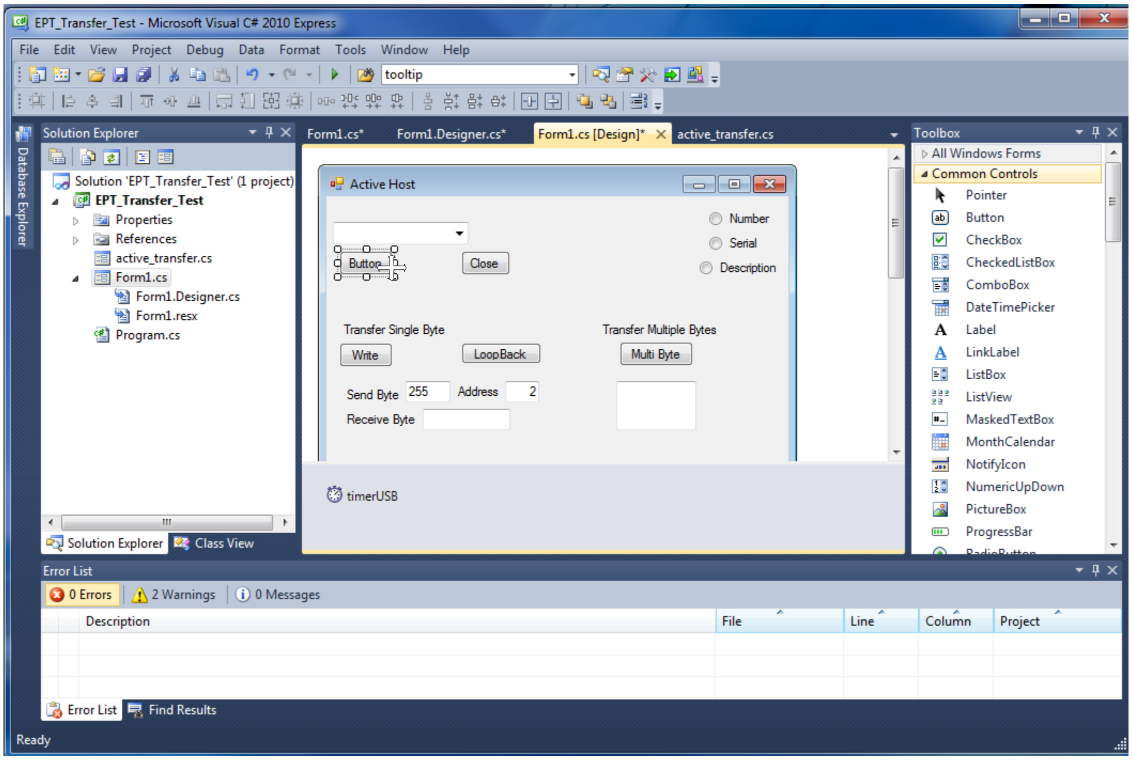
Although, the C# language is very similar to C Code, there are a few major differences. The first is C# .NET environment is event based. A second is C# utilizes classes. This guide will keep the details of these items hidden to keep things simple. However, a brief introduction to events and classes will allow the beginner to create effective programs.

Event based programming means the software responds to events created by the user, a timer event, external events such as serial communication into PC, internal events such as the OS, or other events. The events we are concerned with for our example program are button clicks or dropdown box clicks. The user events occur when the user clicks on a button on the Windows Form or selects a radio button. We will add a button to our example program to show how the button adds an event to the Windows Form and a function that gets executed when the event occurs.

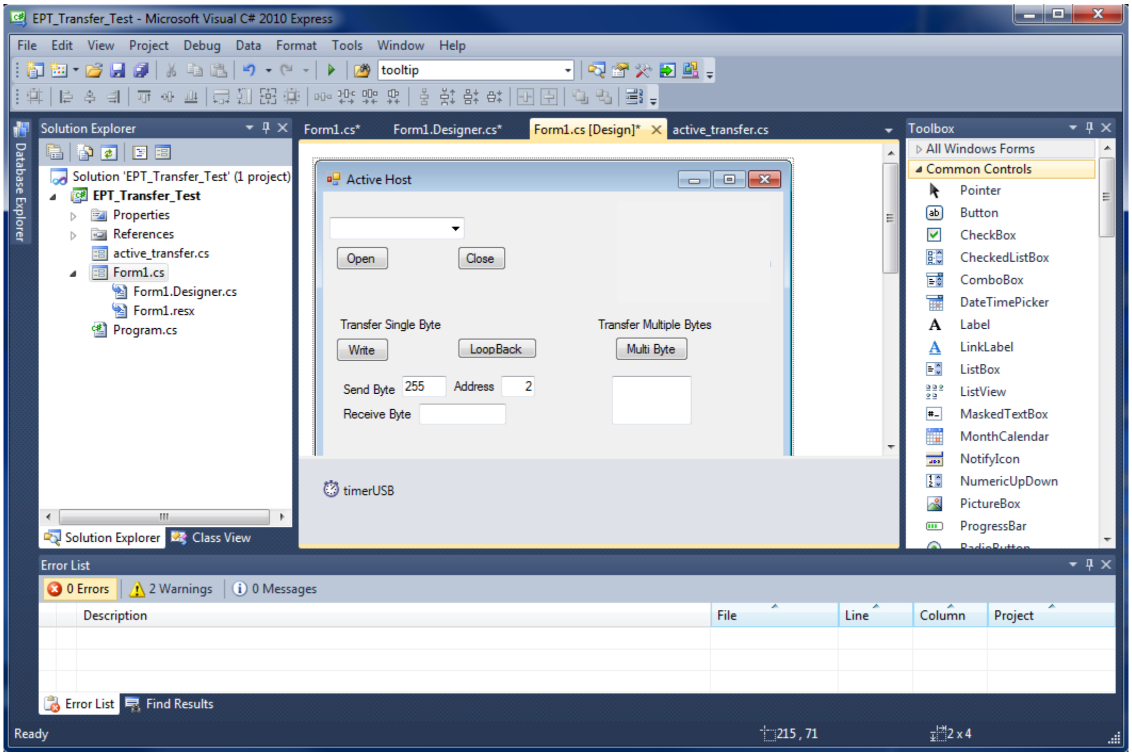
The easiest way to add a button to a form is to double click the Form1.cs in the Solution Explorer. Click on the  button to launch the Toolbox.



Locate the button on the Toolbox, grab and drag the button onto the Form1.cs [Design] and drop it near the top.



Go to the Properties box and locate the (Name) cell. Change the name to “btnOpenDevice”. Locate the Text cell, and change the name to Open.



Double click on the Open button. The C# Explorer will automatically switch to the Form1.cs code view. The callback function will be inserted with the name of the button along with "_click" appended to it. The parameter list includes (object sender, System.EventArgs e). These two additions are required for the callback function to initiate when the "click" event occurs.

Private void btnOpenDevice_click(object sender, System.EventArgs e)

There is one more addition to the project files. Double click on the Form1.Designer.cs file in the Solution Explorer. Locate the following section of code.

```
//
// btnOpenDevice
//
this.btnOpenDevice.Location = new System.Drawing.Point(240, 13);
this.btnOpenDevice.Name = "btnOpenDevice";
this.btnOpenDevice.Size = new System.Drawing.Size(50, 23);
this.btnOpenDevice.TabIndex = 2;
this.btnOpenDevice.Text = "Open";
this.btnOpenDevice.UseVisualStyleBackColor = true;
this.btnOpenDevice.Click += new System.EventHandler(this.btnOpenDevice_Click);
```

This code sets up the button, size, placement, and text. It also declares the "System.EventHandler()". This statement sets the click method (which is a member of the button class) of the btnOpenDevice button to call the EventHandler – btnOpenDevice_Click. This is where the magic of the button click event happens.

```
private void btnOpenDevice_Click(object sender, EventArgs e)
{
    //Open the Device
    OpenDevice();
    lblDeviceConnected.Text = "Device Connected";
}

private void btnCloseDevice_Click(object sender, EventArgs e)
{
    EPT_AH_CloseDeviceByIndex(device_index);
    btnOpenDevice.Enabled = true;
    btnCloseDevice.Enabled = false;

    lblDeviceConnected.Text = " ";
}
```

When btnOpenDevice_Click is called, it calls the function "OpenDevice()". This function is defined in the dll and will connect to the device selected in the combo box. This is a quick view of how to create, add files, and add controls to a C# project. The user is encouraged to spend some time reviewing the online tutorial at http://www.homeandlearn.co.uk/csharp/csharp.html to become intimately familiar with Visual C# .NET programming. In the meantime, follow the examples from the Earth People Technology to perform some simple reads and writes to the EPT USB-CPLD Development System.

The btnOk and btnClose buttons are used to end the application. It calls the function EPT_AH_CloseDeviceByIndex() to remove the device from the Active Host dll. The buttons btnOpen and btnClose have their Enabled parameter set to true and false respectively. The Enabled parameter controls whether the button is allowed to launch an event or not. If it is not enabled, the button is grayed out. At the end of each click event, the Application.Exit() method is called. This exits the form.

```
private void btnOk_Click(object sender, EventArgs e)
{
    EPT_AH_CloseDeviceByIndex(device_index);
    btnOpenDevice.Enabled = true;
    btnCloseDevice.Enabled = false;

    lblDeviceConnected.Text = "";
    Application.Exit();
}

private void btnCancel_Click(object sender, EventArgs e)
{
    EPT_AH_CloseDeviceByIndex(device_index);
    btnOpenDevice.Enabled = true;
    btnCloseDevice.Enabled = false;

    lblDeviceConnected.Text = "";
    Application.Exit();
}
```

The btnStart and btnStop buttons are used to start and stop the EPT-570-AP USB Trasnfer. They call the function EPT_AH_SendTransferControlByte() to set the bit 0 in the control register. The function passes the control byte to the Active Host dll. They both operate on the click event, which are setup in the Form1.Designer.cs file

```
this.btnStart.Click += new System.EventHandler(this.btnStart_Click);
this.btnStop.Click += new System.EventHandler(this.btnStop_Click);
```

The EPT_AH_SendTransferControlByte() requires two parameters, address and control register. The address must correspond to the correct EndTerm in the EPT-570-AP code.

```
private void btnStart_Click(object sender, EventArgs e)
{
    EPT_AH_SendTransferControlByte((char)2, (char)1);
}

private void btnStop_Click(object sender, EventArgs e)
{
    EPT_AH_SendTransferControlByte((char)2, (char)0);
}
```

The button SetScaleFactor will call the ScaleFactorMenuOpenWindow(). This code is explained later. It will set up textboxes, buttons, and labels at runtime for use in retreiving the scale factors for each analog channel.

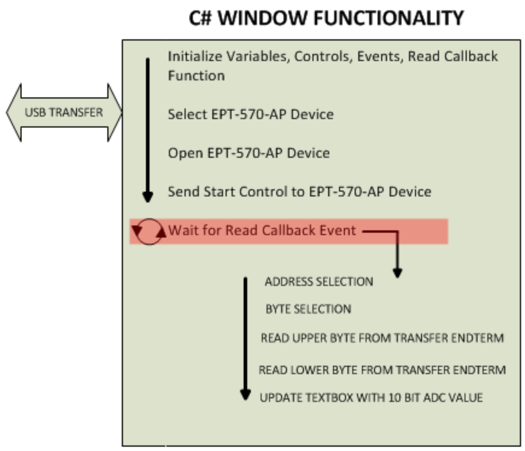
```
private void btnSetScaleFactor_Click(object sender, EventArgs e)
{
    ScaleFactorMenuOpenWindow();
}
```

The buttons RstMonitorX (X = 1 to 6) are used to call the textbox clear method. When this is envoked the text in the textbox will be cleared.

```
private void btnRstMonitor6_Click(object sender, EventArgs e)
{
    tbMonitor6.Clear();
}
```

5.1.9 C# Project EPTReadFunction Callback

When EPTReadFunction() callback is called and passed parameters from the Active



Host dll, it populates the EPTReceiveData object. It then calls EPTParseReceive() function. This function uses a case statement to call the TransferOutReceive() function.

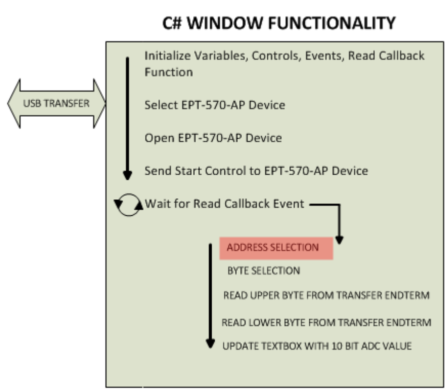
```
private void EPTParseReceive()
{
    switch (EPTReceiveData.Command)
    {
        case TRANSFER_OUT_COMMAND:
            TransferOutReceive();
            break;
        default:
            break;
    }
}
```

TransferOutReceive() is the function that decodes the message, selects the EndTerm address, reads and stores the upper byte, reads and stores the lower byte, and updates the textboxes with the digitized values from the Arduino analog conversion. When a transfer message has been received from the EPT-570-AP, the TransferOutReceive() function uses the EPTReceiveData object address to conditionally branch to a set of statements. This is done using a switch/case statement.

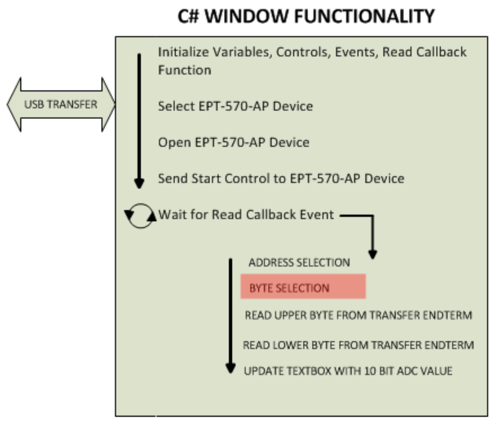
```
public void TransferOutReceive()
{

    //Store the address history from the EPT Receive Object
    SecondPreviousActualAddr = FirstPreviousActualAddr;
    FirstPreviousActualAddr = EPTReceiveData.Address;

    //Main Conditional Branch for populating the Textboxes
    switch (EPTReceiveData.Address)
    {
        case TRANSFER_OUT_ADDRESS_1:
            // Send the one character buffer.
            if (DisplayAddress_1 & FirstDisplayByte)
            {
```

The switch will select one of the case statements based on the following collection of address's:

- TRANSFER_OUT_ADDRESS_1
- TRANSFER_OUT_ADDRESS_2
- TRANSFER_OUT_ADDRESS_3
- TRANSFER_OUT_ADDRESS_4
- TRANSFER_OUT_ADDRESS_5
- TRANSFER_OUT_ADDRESS_6



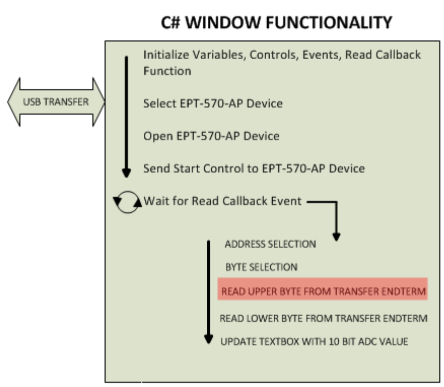
When the code enters the TRANSFER_OUT_ADDRESS_x case statement for the first time, the DisplayAddress_x should be set to the same address as EPTReceiveData.Address. The FirstDisplayByte should be high. This will cause the first if statement to be entered.




```
case TRANSFER_OUT_ADDRESS_1:
    // Send the one character buffer.
    if (DisplayAddress_1 & FirstDisplayByte)
    {
        AnalogValue = 0;
        FirstDisplayByte = false;
        AnalogValue = AnalogValue | ((int)EPTReceiveData.cBlockBuf[0] << 8);
    }
```

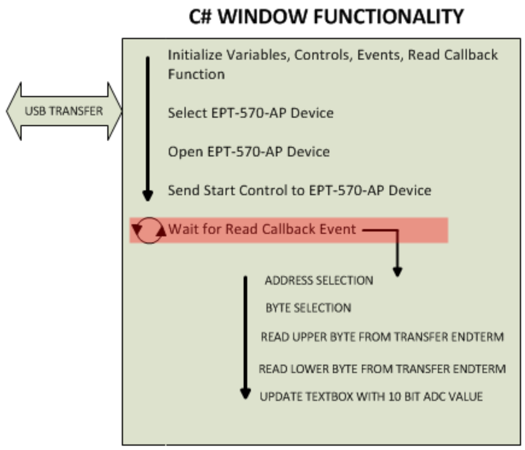
When it is entered, three things happen:

1. the AnalogValue is cleared to zero. This is done to clear out any value that was previously in there.
2. The FirstDisplayByte is set to false so that the next time the case statement TRANSFER_OUT_ADDRESS_x is entered, the lower byte will be added to the first 8 bits of AnalogValue.
3. The byte buffer EPTReceiveData.cBlockBuf[0] is right shifted by eight bits. It is then added to AnalogValue. This will store the upper byte from the EPT-570-AP to the upper 8 bits of AnalogValue.

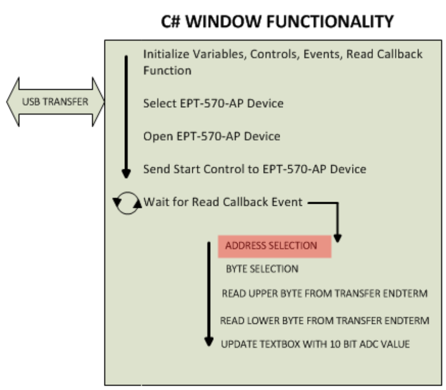


When the third statement in the if statement has completed, the case statement is exited and the thread is ended.

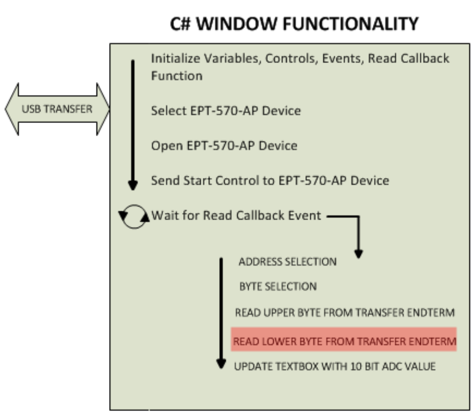
The next time the ReadCallback is called, the switch conditional is entered again.



This time the EPTReceiveData.Address will again be equal to TRANSFER_OUT_ADDRESS_x and FirstDisplayByte will be low. So, again the first case statement will be entered.



The second if conditional branch will be entered.

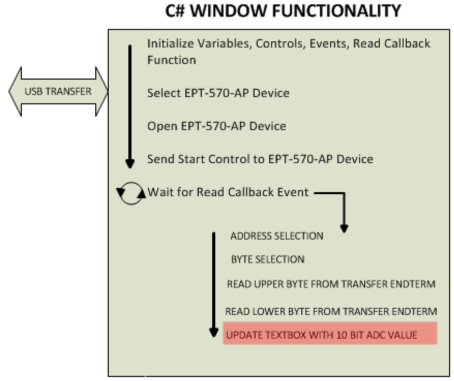


```
else if (DisplayAddress_1 & !FirstDisplayByte)
{
    string WriteRcvChar = "";
    FirstDisplayByte = true;

    AnalogValue = AnalogValue | ((int)EPTReceiveData.cBlockBuf[0]);

    if (ScaleFactor1 != 0.0)
    {
        FloatValue = AnalogValue * ScaleFactor1;
        WriteRcvChar = String.Format("{0}", FloatValue);
    }
    else
        WriteRcvChar = String.Format("{0}", AnalogValue);
```

When it is entered, the following occurs:

1. The WriteRcvChar is cleared to zero. This is done to clear out any value that was previously in there. This variable is used to collect the modified AnalogValue and send it a thread to be written to the Textbox.
2. The FirstDisplayByte is set to true so that the next time the case statement TRANSFER_OUT_ADDRESS_x is entered, the upper byte will be added to the first 8 bits of AnalogValue.
3. The byte buffer EPTReceiveData.cBlockBuf[0] is added to AnalogValue. This will store the lower byte from the EPT-570-AP to the lower 8 bits of AnalogValue.
4. The ScaleFactorx variable is checked for nonzero value. If is zero, the AnalogValue is converted to a string and stored in WriteRcvChar. This will pass the raw counts from the output of the Arduino ADC channel into WriteRcvChar. If the ScaleFactorx is nonzero, that tells the code that a scale factor is present and the code must multiply this value by the raw counts from the Arduino ADC channel. This is done by using a float value labeled: FloatValue. This value is set to the result of AnalogValue multiplied by the ScaleFactorx.
5. The results of the scalefactor conditional branch is converted to a string then stored in WriteRcvChar.

C# WINDOW FUNCTIONALITY



```
        DisplayAddress_1 = false;
        DisplayAddress_2 = true;
        DisplayAddress_3 = false;
        DisplayAddress_4 = false;
        DisplayAddress_5 = false;
        DisplayAddress_6 = false;

        Thread Display1Thread = new Thread(new ParameterizedThreadStart(DisplayValue1));
        Display1Thread.Start(WriteRcvChar);
    }
```

6. The next several statements update the DisplayAddress_x variables. It sets the current DisplayAddress_x to false and sets the next incremented DisplayAddress_x to true. This is done so that the C# code can be synchronized with the code on the Arduino.
7. Next, the WriteRcvChar value is sent to the thread that will populate the textbox. Calling a thread is similar to calling a function. However, when you call a function in the traditional C language, the calling instruction is halted while the function instructions are executed. When the function is complete, the execution is handed back to the calling instruction and it continues to execute and the next instruction after that is executed and so on. When a thread is commanded to execute, the Windows OS will execute instructions for the function in the thread and simultaneously continue execution of instructions in the calling code. The Windows OS allows hundreds of threads to execute simultaneously. It maintains the memory and execution requirements for each thread transparently to the user. C# is brilliant because you can easily call a thread and forget about it. It handles everything for you, it even cleans up the memory after the thread has completed. So, to launch our "write to textbox" thread, use the ParameterizedThreadStart() function. This allows us to pass an object, "WriteRcvChar" to the function.

```
public void DisplayValue1(object WriteRcvChar)
{
    this.Invoke(new MethodInvoker(delegate() { tbMonitor1.Text = (string)WriteRcvChar; }));
}
```

8. Finally, the textbox, "tbMonitor_x" is updated. This is done by using the Invoke-Method instruction. A method is a function in a class. In winforms, Invoke is used to call a method on the UI thread – without it can cause an exception by updating the UI from another thread. Effectively, what Invoke does is ensure that the code you are calling occures on the thread that the control "lives on" effectively preventing cross threaded exceptions. Further, the .NET framework creates multiple threads when using winforms. The textboxes "live" on a controls thread, while your code to update the textbox "lives" on a user-background thread. These two threads are not synchronized. So, your code must ask the textbox thread (called the UI thread) politely if it could update the text

characters in the box. The UI thread will decide when it is ready to stop and handle the request from the background thread.

Once the Invoke—Method has been called the EPTTransferOut thread is complete and the textbox will be updated with the 10 bit digitized sample from the Arduino selected channel.

Then repeat the above steps for the rest of the five channels.

```
case TRANSFER_OUT_ADDRESS_1:
    // Send the one character buffer.
    if (DisplayAddress_1 & FirstDisplayByte)
    {
        AnalogValue = 0;
        FirstDisplayByte = false;
        AnalogValue = AnalogValue | ((int)EPTReceiveData.cBlockBuf[0] << 8);
    }
    else if (DisplayAddress_1 & !FirstDisplayByte)
    {
        string WriteRcvChar = "";
        FirstDisplayByte = true;

        AnalogValue = AnalogValue | ((int)EPTReceiveData.cBlockBuf[0]);

        if (ScaleFactor1 != 0.0)
        {
            FloatValue = AnalogValue * ScaleFactor1;
            WriteRcvChar = String.Format("{0}", FloatValue);
        }
        else
            WriteRcvChar = String.Format("{0}", AnalogValue);

        DisplayAddress_1 = false;
        DisplayAddress_2 = true;
        DisplayAddress_3 = false;
        DisplayAddress_4 = false;
        DisplayAddress_5 = false;
        DisplayAddress_6 = false;

        Thread Display1Thread = new Thread(new ParameterizedThreadStart(DisplayValue1));
        Display1Thread.Start(WriteRcvChar);
```

```
0] << 8);

0]);
            else
                WriteRcvChar = String.Format("{0}", AnalogValue);

            DisplayAddress_1 = false;
            DisplayAddress_2 = false;
            DisplayAddress_3 = true;
            DisplayAddress_4 = false;
            DisplayAddress_5 = false;
            DisplayAddress_6 = false;

        Thread Display2Thread = new Thread(new ParameterizedThreadStart(DisplayValue2));
        Display2Thread.Start(WriteRcvChar);
```

```
uf[0] << 8);

uf[0]);
                WriteRcvChar = String.Format("{0}", FloatValue);
            }
            else
                WriteRcvChar = String.Format("{0}", AnalogValue);

            DisplayAddress_1 = false;
            DisplayAddress_2 = false;
            DisplayAddress_3 = false;
            DisplayAddress_4 = true;
            DisplayAddress_5 = false;
            DisplayAddress_6 = false;

        Thread Display3Thread = new Thread(new ParameterizedThreadStart(DisplayValue3));
        Display3Thread.Start(WriteRcvChar);
```

```
8);
            else
                WriteRcvChar = String.Format("{0}", AnalogValue);

            DisplayAddress_1 = false;
            DisplayAddress_2 = false;
            DisplayAddress_3 = false;
            DisplayAddress_4 = false;
            DisplayAddress_5 = false;
            DisplayAddress_6 = true;

        Thread Display5Thread = new Thread(new ParameterizedThreadStart(DisplayValue5));
        Display5Thread.Start(WriteRcvChar);
```

```
Buf[0] << 8);

Buf[0]);
            else
                WriteRcvChar = String.Format("{0}", AnalogValue);

            DisplayAddress_1 = false;
            DisplayAddress_2 = false;
            DisplayAddress_3 = false;
            DisplayAddress_4 = false;
            DisplayAddress_5 = true;
            DisplayAddress_6 = false;

        Thread Display4Thread = new Thread(new ParameterizedThreadStart(DisplayValue4));
        Display4Thread.Start(WriteRcvChar);
```

```
            if (ScaleFactor6 != 0)
            {
                FloatValue = AnalogValue * ScaleFactor6;
                WriteRcvChar = String.Format("{0}", FloatValue);
            }
            else
                WriteRcvChar = String.Format("{0}", AnalogValue);

            DisplayAddress_1 = true;
            DisplayAddress_2 = false;
            DisplayAddress_3 = false;
            DisplayAddress_4 = false;
            DisplayAddress_5 = false;
            DisplayAddress_6 = false;

            Thread Display6Thread = new Thread(new ParameterizedThreadStart(DisplayValue6));
        Display6Thread.Start(WriteRcvChar);
```

Now that we have the code to perform the decode, store the digitized value and display to textbox, we need to add error correction code. This code is added to handle the case in which we start up the Analog Monitor C# code and we don't know what channel or which byte (upper/lower) is being received.

We add two conditional branches to the case statement of TRANSFER_OUT_ADDRESS_x. These two branches will handle the case when DisplayAddress_x is low. This means that for the EPTReceiveData.Address received, the DisplayAddress_x was not set to the correct address previously.

```
else if (!DisplayAddress_1 & FirstDisplayByte)
{
    FirstPreviousCalcAddr = EPTReceiveData.Address;
    FirstDisplayByte = false;
    AnalogValue = 0;

    DisplayAddress_1 = true;
    DisplayAddress_2 = false;
    DisplayAddress_3 = false;
    DisplayAddress_4 = false;
    DisplayAddress_5 = false;
    DisplayAddress_6 = false;
}
else if (!DisplayAddress_1 & !FirstDisplayByte)
{
    SecondPreviousCalcAddr = EPTReceiveData.Address + 1;
    FirstDisplayByte = true;
    AnalogValue = 0;
    if ((FirstPreviousActualAddr == FirstPreviousCalcAddr) &
        (SecondPreviousActualAddr != SecondPreviousCalcAddr))
    {
        DisplayAddress_1 = false;
        DisplayAddress_2 = true;
        DisplayAddress_3 = false;
        DisplayAddress_4 = false;
        DisplayAddress_5 = false;
        DisplayAddress_6 = false;
    }
    else
    {
        DisplayAddress_1 = true;
        DisplayAddress_2 = false;
        DisplayAddress_3 = false;
        DisplayAddress_4 = false;
        DisplayAddress_5 = false;
        DisplayAddress_6 = false;
    }
}
```

We will need several variables to accomplish error correction. These variables are:

```
//Address variables to keep track of which Transfer
//group should store the Display byte from the EPT-570
public bool DisplayAddress_1 = false;
public bool DisplayAddress_2 = false;
public bool DisplayAddress_3 = false;
public bool DisplayAddress_4 = false;
public bool DisplayAddress_5 = false;
public bool DisplayAddress_6 = false;

//Address variables to store history of the addresses
//from the EPT Receive object
public int FirstPreviousActualAddr = 0;
public int SecondPreviousActualAddr = 0;

//Address variables to store history of the addresses
//determined by the case statements
public int FirstPreviousCalcAddr = 0;
public int SecondPreviousCalcAddr = 0;
```

The DisplayAddress_x variables are used to check whether the Arduino channel number and the C# code are in sync. The FirstPreviousActualAddr and SecondPreviousActualAddr are used to record the previous two Arduino channel selections. The FirstPreciousCalcAddr and SecondPreviousCalcAdddr are used to record the address's that the C# code calculates in response to EPTReceiveData.Address and conditional branches.

In the first error correction branch, EPTReceiveData.Address will select a case statement with TRANSFER_OUT_ADDRESS_x but the DisplayAddress_y is not the same value. The FirsDisplayByte is high, so the following happens.

1. Each time a byte is received, SecondPreviousActualAddr is set to FirstPreviousActualAddr. Also, FirstPreviousActualAddr is set to EPTReceiveData.Address. This ensures that the older address is in the Second… and the newest address is in First…
2. Set FirstPreviousCalcAddr to EPTReceiveData.Address.
3. Set FirstDisplayByte to false or low.
4. Set AnalogValue to zero
5. Set DisplayAddress_x to high. This will select the current address of EPTReceiveData.Address. This assumes that the current selection of EPTReceiveData.Address is the upper byte of the digitized value and the following selection of EPTReceiveData.Address will be the lower byte. If that is the case then we will be in sync with the Arduino channel selection and no further error correction will be needed.

In the second error correction branch, EPTReceiveData.Address will select a case statement with TRANSFER_OUT_ADDRESS_x but the DisplayAddress_y is not the same value. The FirsDisplayByte is low, so the following happens.

1. Set SecondPreviousCalcAddr equal to the incremetn of EPTReceiveData.Address. This makes the assumption that the next byte transferred will be the upper byte of the digitized value and that means that the address will be incremented.

2. FirstDisplayByte is set to true.
3. AnalogValue is set to zero.
4. A conditional branch is used to check if the FirstPreviousActualAddr is equal to FirstPreviousCalcAddr. Also SecondPreviousActualAddr is checked for equivalency with SecondPreviousCalcAddr. This is done to check the history of the address's that have been used to get to this conditional branch. If the history is congruent, then the DisplayAddress_x will be set to the next address. If the history is not congruent, DisplayAddress_x will be set to the current address.

This is all that is necessary to synchronize the Arudino channel selection and the C# display functions. Use the table below to verify that the error correction code will synchronize with the Arduino channel no matter what the channel is or whether the C# code is receiving the upper digitized byte or lower digitized bye.

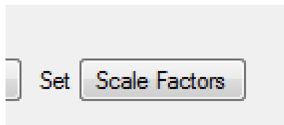
Arduino Channel	EPTReceiveData.Address	Upper ADC Byte	Lower ADC Byte	Address Calculated	FirstDisplayByte	FirstPreviousActualAddr	SecondPreviousActualAddr	FirstPreviousCalcAddr	SecondPreviousCalcAddr
Case 1: Arduino Channel is 1, Sending Upper Byte	1	1	0	0	1	0	0	0	0
	1	1	0	0	1	1	0	0	0
	1	1	0	1	0	1	0	1	0
	1	0	1	1	0	1	1	1	0
	1	0	1	2	1	1	1	1	0
	2	1	0	2	1	2	1	1	0
	2	1	0	2	0	2	1	1	0
	2	0	1	2	0	2	2	1	0
	2	0	1	3	1	2	2	1	0
	3	1	0	3	1	3	2	1	0
	3	1	0	3	0	3	2	1	0
	3	0	1	3	0	3	3	1	0
	3	0	1	4	1	3	3	1	0
Case 2: Arduino Channel is 1, Sending the Lower Byte									
	1	0	1	0	1	1	0	0	0
	1	0	1	1	0	1	0	1	0
	2	1	0	1	0	2	1	1	0
	2	1	0	2	0	2	1	1	3
	2	0	1	2	0	2	2	1	3
	2	0	1	3	1	2	2	1	3
	3	1	0	3	1	3	2	1	3
	3	1	0	3	0	3	2	1	3
	3	0	1	3	0	2	3	1	3
	3	0	1	4	1	2	3	1	3

5.1.10 C# Project Scale Factor Selection

When both the upper and lower bytes have been received from the EPT-570-AP, the AnalogValue has the ADC counts from the Arduino channel. But this is just a digital representation of the analog signal sampled at the ADC input. To convert this into a real voltage, we have to multiply the raw counts by the scale factor. First we need to calculate what the scale factor should be. This is accomplished by taking the full scale deflection of the ADC, this means the maximum voltage the ADC can take, for the Arduino Uno it is 5 Volts. Then divide this number by the total number of counts of the ADC, for the Arduino Uno's 10 bit ADC, this is 2^{10} = 1024. So, the scale factor is 5V/1024Counts. Our scale factor is 0.0048828 Volts/Counts. To set the scale factor for each Arduino channel digitized value, we added all the code to file ScaleFactorMenu.cs. The top of the file declares the namespace to add the code to, and the class that is belongs to.

```
namespace EPT_Analog_Monitor
{

    public partial class EPT_Analog_Monitor
    {
```

This code is activated when the



button is clicked. It calls the ScaleFactorMenuOpenWindow() function.

```
public void ScaleFactorMenuOpenWindow()
 {
     this.AutoSize = false;
```

The code will expand the WinForm and add textboxes, buttons, and labels at run time. The code looks the same as if we used the ‘drag and drop’ method from the Visual Studio Toolbox.

```
//Textboxes to add
TextBox ScaleFactor1TextBox = null;
TextBox ScaleFactor2TextBox = null;
TextBox ScaleFactor3TextBox = null;
TextBox ScaleFactor4TextBox = null;
TextBox ScaleFactor5TextBox = null;
TextBox ScaleFactor6TextBox = null;

//Buttons to add
Button ScaleFactorExitButton = null;

//Labels to add
Label ScaleFactor1Label = null;
Label ScaleFactor2Label = null;
Label ScaleFactor3Label = null;
Label ScaleFactor4Label = null;
Label ScaleFactor5Label = null;
Label ScaleFactor6Label = null;
Label ScaleFactorStatus = null;

//Repeat and delay for Send File
public float ScaleFactor1 = 0;
public float ScaleFactor2 = 0;
public float ScaleFactor3 = 0;
public float ScaleFactor4 = 0;
public float ScaleFactor5 = 0;
public float ScaleFactor6 = 0;
```

Each textbox is setup with the following code.

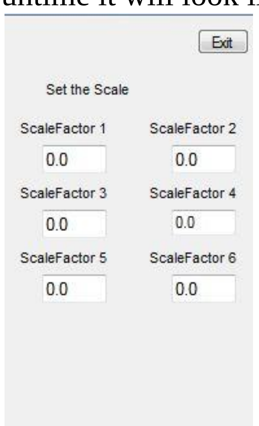
```
//=====================================
// Scale Factor Menu Add TextBoxes
//=====================================

//Textbox to Enter Path and Filename of File to Send
ScaleFactor1TextBox = new TextBox();
ScaleFactor1TextBox.Location = new System.Drawing.Point(420, 100);
ScaleFactor1TextBox.Size = new System.Drawing.Size(50, 20);
ScaleFactor1TextBox.Font = new System.Drawing.Font("Microsoft Sans Serif", 9.75F, System
ScaleFactor1TextBox.Visible = true;
ScaleFactor1TextBox.Text = "0.0";
this.ScaleFactor1TextBox.KeyPress += new System.Windows.Forms.KeyPressEventHandler(this.
this.Controls.Add(ScaleFactor1TextBox);
//Resize the window for both textboxes.
this.Size = new Size(600, 400);
```

Each button and label is setup with the following code.

```
//====================================
// Scale Factor Menu Add Buttons
//====================================


//Exit button to end SendMenu
ScaleFactorExitButton = new Button();
ScaleFactorExitButton.Location = new Point(540, 10);
ScaleFactorExitButton.FlatAppearance.BorderSize = 1;
ScaleFactorExitButton.Text = "Exit";
ScaleFactorExitButton.Size = new System.Drawing.Size(40, 20);
//this.toolTip1.SetToolTip(this.ScaleFactorExitButton, "Exit");
this.Controls.Add(ScaleFactorExitButton);
ScaleFactorExitButton.Click += new EventHandler(ScaleFactorExitButton_Click);

//====================================
// Scale Factor Menu Add Labels
//====================================

//Add File to send Label to Send Textbox
ScaleFactor1Label = new Label();
ScaleFactor1Label.Location = new Point(400, 80);
ScaleFactor1Label.Font = new Font("Arial", 8);
ScaleFactor1Label.Text = "ScaleFactor 1";
this.Controls.Add(ScaleFactor1Label);
```

When all of the textboxes, buttons, and lables are set up, the ScaleFactorMenuSetAnchor() function is called. This makes sure that all controls are pinned to the top left corner of the Winform. If the user resizes the window, all of the controls: textboxes, buttons, and labels will get resized along with the main Winform.

When the window is complete at runtime it will look like:



To add a value to the ScaleFactor_x textbox, just type in the number. The “KeyPress” event will be raised by typing in the textbox. We add a subsctiption to this event. When the event occurs, we execute our code to retreive the scale factor value.

```
private void ScaleFactor1TextBox_KeyPress(object sender, EventArgs e)
{
    //Read the scale factor 1 from text box.
    ScaleFactor1 = (float)Convert.ToDouble(ScaleFactor1TextBox.Text);

 }
```

For more information about events and how to subscribe to them, see this web page. http://www.homeandlearn.co.uk/csharp/csharp_s9p1.html

When we execute our code, the ScaleFactorX is set equal to the string value of the textbox, ScaleFactorXTextBox.Text. This means the number retrieved from the textbox is in the wrong format, ie a string. So, we need to convert the string into a float value for use as a scale factor. To do this, use the "Convert.ToDouble" method. Then recast the double as a float, ScaleFactorX = (float)Convert.ToDouble(ScaleFactorXTextBox.Text);

Repeat this KeyPress event for all six ScaleFactor textboxes.

```
private void ScaleFactor1TextBox_KeyPress(object sender, EventArgs e)
{
    //Read the scale factor 1 from text box.
    ScaleFactor1 = (float)Convert.ToDouble(ScaleFactor1TextBox.Text);

}
```

```
public void ScaleFactor2TextBox_KeyPress(object sender, EventArgs e)
{
    //Read the scale factor 2 from text box.
    ScaleFactor2 = (float)Convert.ToDouble(ScaleFactor2TextBox.Text);

}
```

```
private void ScaleFactor3TextBox_KeyPress(object sender, EventArgs e)
{

    //Read the scale factor 3 from text box.
    ScaleFactor3 = (float)Convert.ToDouble(ScaleFactor3TextBox.Text);
}
```

```
private void ScaleFactor4TextBox_KeyPress(object sender, EventArgs e)
{

    //Read the scale factor 4 from text box.
    ScaleFactor4 = (float)Convert.ToDouble(ScaleFactor4TextBox.Text);
}
```

```
private void ScaleFactor5TextBox_KeyPress(object sender, EventArgs e)
{

    //Read the scale factor 5 from text box.
    ScaleFactor5 = (float)Convert.ToDouble(ScaleFactor5TextBox.Text);

}
```

```
private void ScaleFactor6TextBox_KeyPress(object sender, EventArgs e)
{

    //Read the scale factor 6 from text box.
    ScaleFactor6 = (float)Convert.ToDouble(ScaleFactor6TextBox.Text);
}
```

Once the ScaleFactor is updated, it will be multiplied by the AnalogValue for the appropriate channel on the next display textbox update for the given channel.

```
else if (DisplayAddress_1 & !FirstDisplayByte)
{
    string WriteRcvChar = "";
    FirstDisplayByte = true;

    AnalogValue = AnalogValue | ((int)EPTReceiveData.cBlockBuf[0]);

    if (ScaleFactor1 != 0.0)
    {
        FloatValue = AnalogValue * ScaleFactor1;
        WriteRcvChar = String.Format("{0}", FloatValue);
    }
    else
        WriteRcvChar = String.Format("{0}", AnalogValue);
```

The ScaleFactorExitButton_Click event calls the shutdown of the ScaleFactor Menu. It disposes of textboxes, buttons, and labels and resets the Winform to its original dimensions.

```
private void ScaleFactorExitButton_Click(object sender, EventArgs e)
{
    //TextBox to Dispose
    ScaleFactor1TextBox.Dispose();
    ScaleFactor2TextBox.Dispose();
    ScaleFactor4TextBox.Dispose();
    ScaleFactor5TextBox.Dispose();
    ScaleFactor6TextBox.Dispose();

    //Buttons to Dispose
    ScaleFactorExitButton.Dispose();

    //Labels to Dispose
    ScaleFactor3Label.Dispose();
    ScaleFactor4Label.Dispose();
    ScaleFactor1Label.Dispose();
    ScaleFactor5Label.Dispose();
    ScaleFactor2Label.Dispose();
    ScaleFactor6Label.Dispose();
    ScaleFactorStatus.Dispose();

    //Size the Window to its original size
    this.Size = new System.Drawing.Size(400, 400);
    //Anchor the textbox to the Windows Form.
    this.Anchor = (AnchorStyles.Top | AnchorStyles.Bottom | AnchorStyles.Left);

}
```

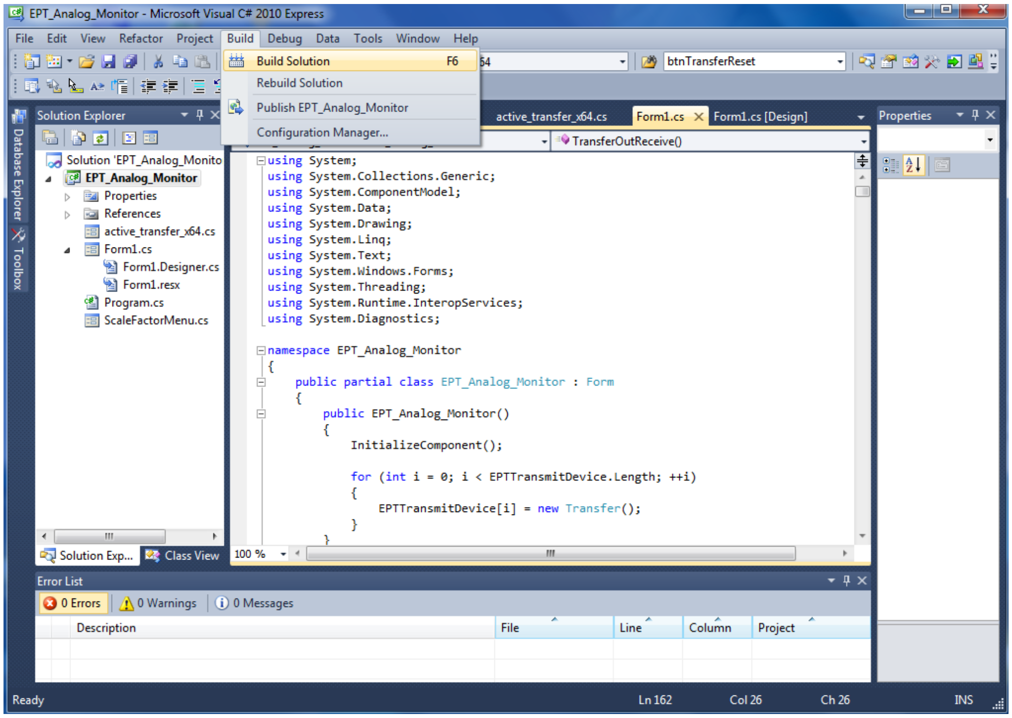
5.1.11 C# Project Completion

This is all that is needed for the Analog Monitor project. The Arduino will generate a 10 bit digitized word for each channel. It then transmits that word to the CPLD using the Write_Enable, Address and data pins. The CPLD transmits each 10 bit word to the PC using the Active_Transfer EndTerm, Active_Transfer Library, and One Hot State Machine. The dll reads the 10 bit word into local memory. It then calls the Callback function, EPTReadFunction. Each 10 bit value is finally displayed to screen using the TransferOutReceive() function.

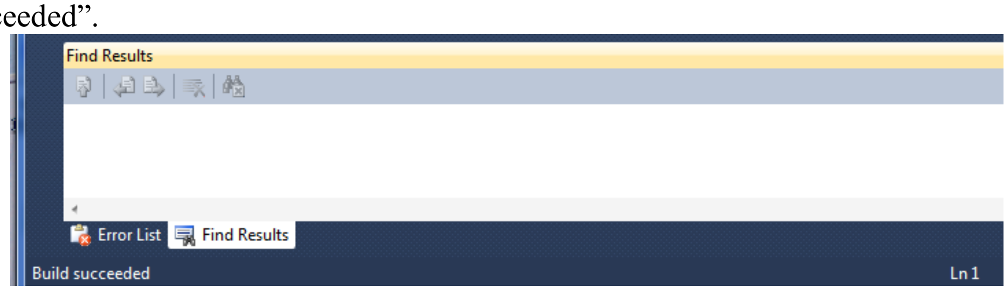
5.2 PC: Compiling the Active Host Application

Building the Analog_Monitor project will compile the code in the project and produce an executable file. It will link all of the functions declared in the opening of the Analog_Monitor Class with the Active Host dll. The project will also automatically link the FTD2XX.dll to the object code.

To build the project, go to Debug->Build Solution.



The C# Express compiler will start the building process. If there are no errors with code syntax, function usage, or linking, then the environment responds with “Build Succeeded”.



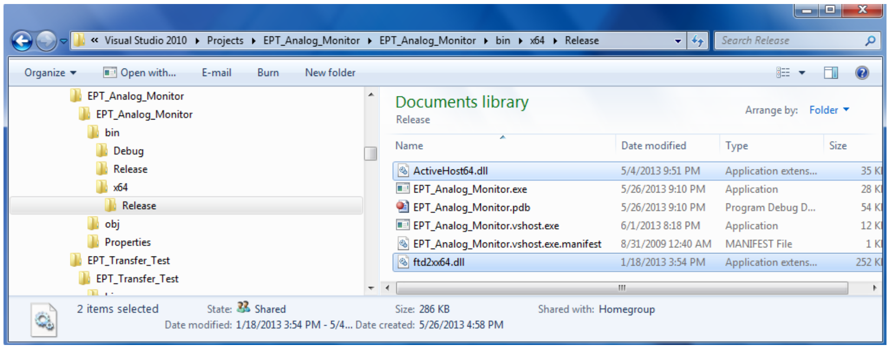
If the build fails, you will have to examine each error in the “Error List” and fix it accordingly. If you cannot fix the error using troubleshooting methods, post a topic in the Earth People Technology Forum. All topics will be answered by a member of the technical staff as soon as possible.

5.2.1 Adding the DLL’s to the Project

Locate the UNO_ANALOG_MONITOR_PROJECT_CD installed on your PC. Browse to the Projects_ActiveHost folder (choose either the 32 bit or 64 bit version, depending on whether your OS is 32 or 64 bit). Open the Bin folder, copy the following files:

- ActiveHostXX.dll
- ftd2xxXX.dll

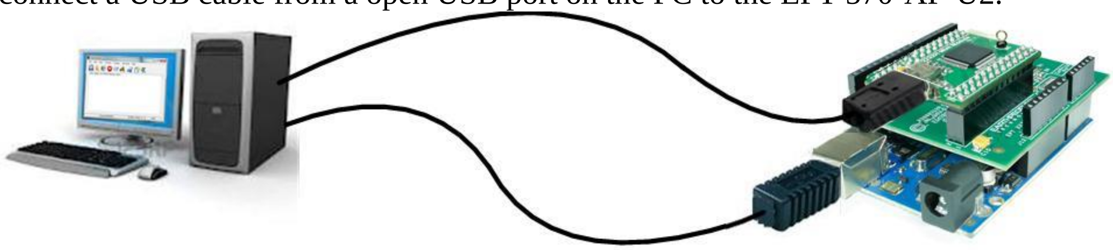
and paste them in the EPT_Analog_Monitor\EPT_Analog_Monitor\bin\x64\Release folder of your EPT_Analog_Monitor project.



At this point, the environment has produced an executable file and is ready for testing. Next, we will connect everything together and see it collect data and display it.

6 Connecting the Project Together

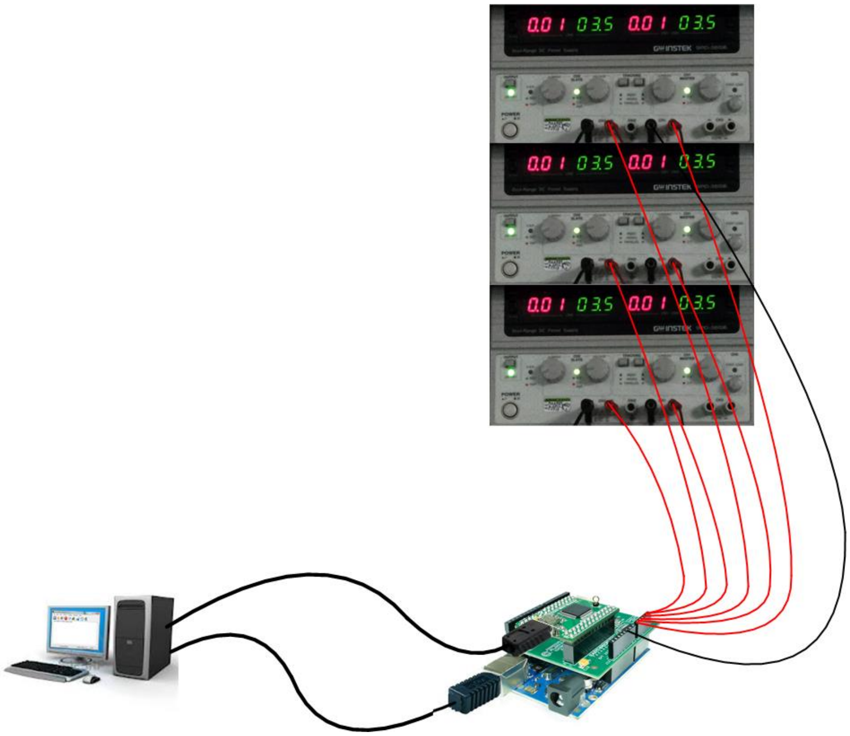
Now we will connect the Arduino, EPT 570-AP-U2, and the PC to make an Analog Monitor. First, connect a USB cable from a USB port on the PC to the Arduino. Second, connect a USB cable from a open USB port on the PC to the EPT 570-AP-U2.



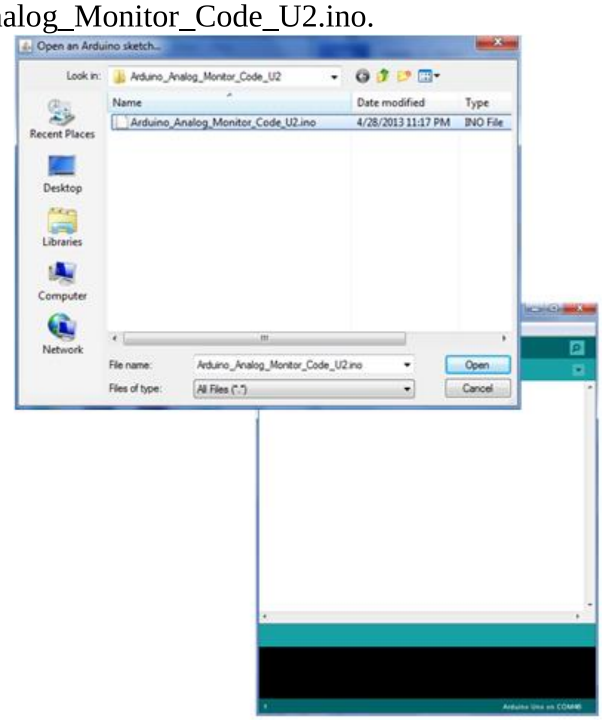
Next, let's connect the Six 5VDC Power Supplies to the analog inputs of the Arduino. We will do the by using the following parts:

- 6 Pin 2.54 mm Male Header
- 10 Pin 2.54 mm Male Header
- Six 5VDC Power Supplies
- Five Black Banana Lead jumpers to connect the Power Supplies together
- One Black Banana Clip Lead to connect the Power Supplies to the Arduino
- Six Red Banana Clip Leads to connect the Power Supplies to the Arduino

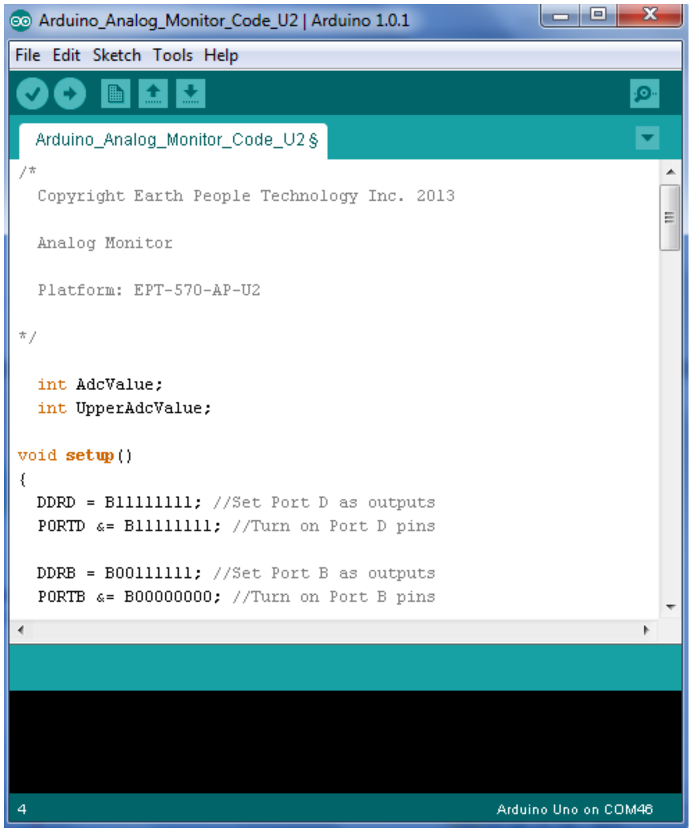
Connect the 10 Pin 2.54 mm Male Header into the J12 connector of the EPT-570-AP board. Next, connect the 6 Pin 2.54 mm Male Header into the J9 connector of the EPT-570-AP board. Connect the black banana jumpers between the grounds of all the supplies. Connect the black banana clip lead to one of the power supply grounds and Pin 7 of J12. Connect one red banana clip lead to each of the power supply positive outputs and connect to one of the pins on the J9 connector.



Next, open the Arduino IDE and select File->Open and select your sketch created earlier, Arduino_Analog_Monitor_Code_U2.ino.

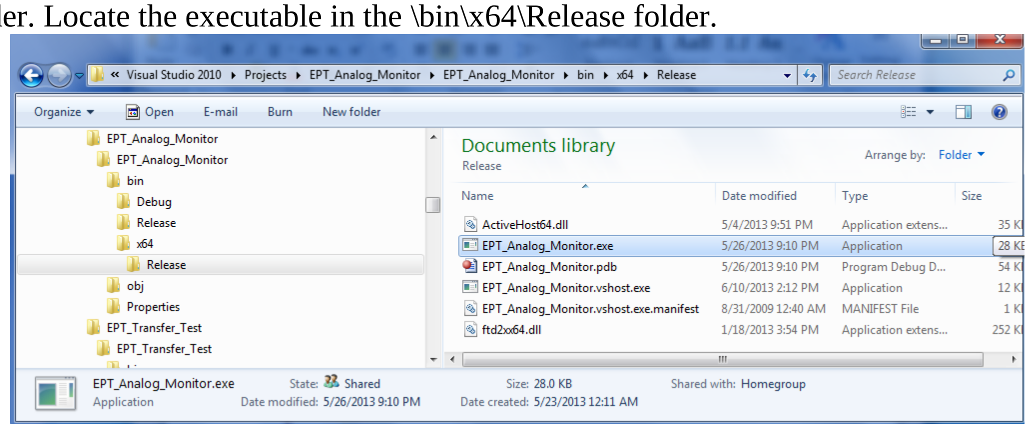


Select the file and click Open. The sketch will now populate the Arduino IDE window. Compile and Download the sketch into the Arduino microcontroller using the Upload button.

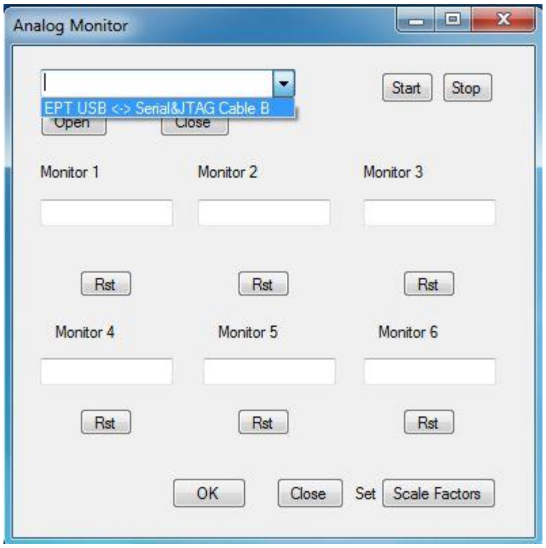


The Arduino IDE will compile the project, then transmit the machine level code into the ATMega328 SRAM to start the program.

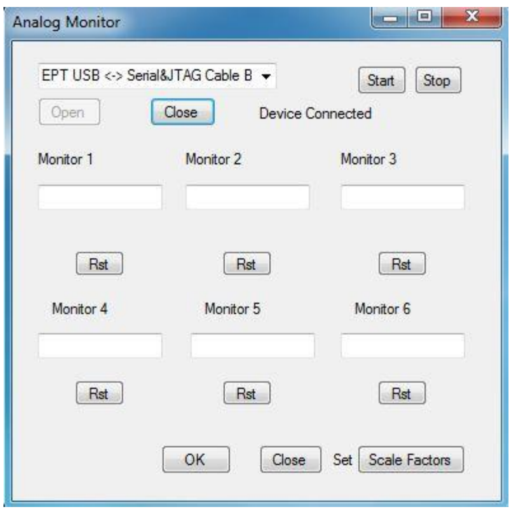
The CPLD should already be programmed with its Analog Monitor Project.
Open the EPT Analog Monitor on the PC by browsing to the Analog Monitor project folder. Locate the executable in the \bin\x64\Release folder.



Initiate the application by double clicking the application icon in the \Release folder of the project. The application will open and automatically load the Active Host dll. The application will locate the EPT 570-AP-U2 device. Next, the combo box at the top will be populated with the name of the device.

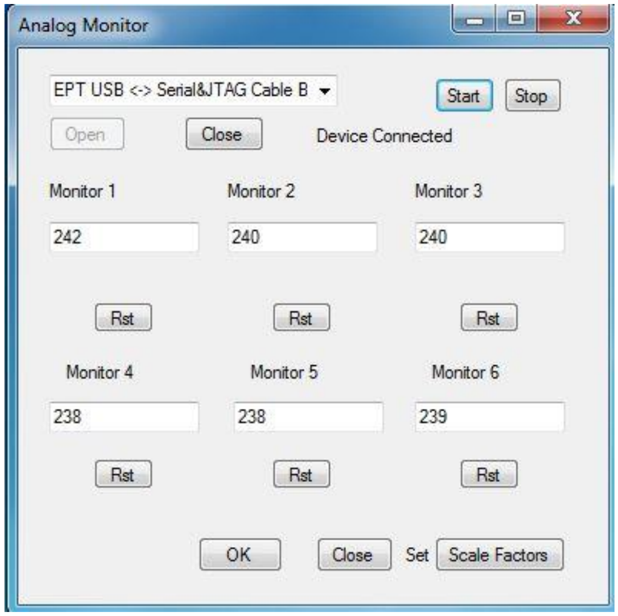


Select the EPT 570-AP device and click the Open button. If the Active Host application connects to the device, a label will indicate "Device Connected".

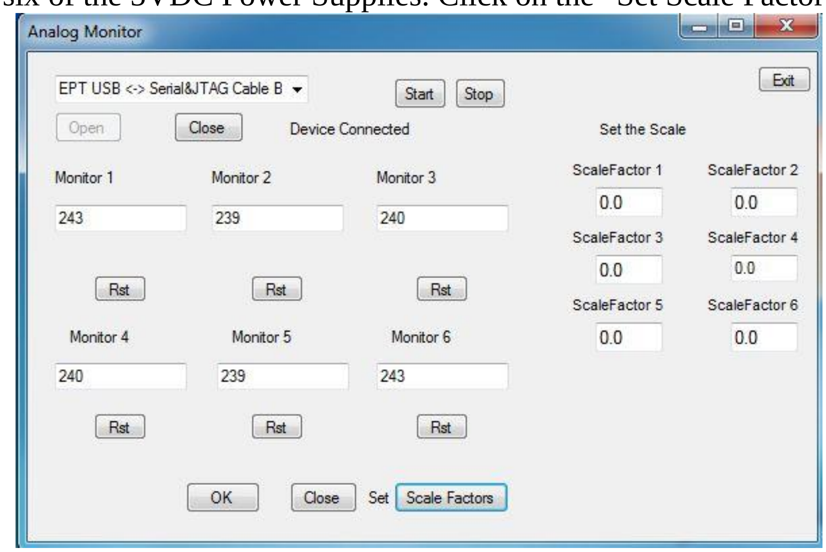


6.1 Testing the Project

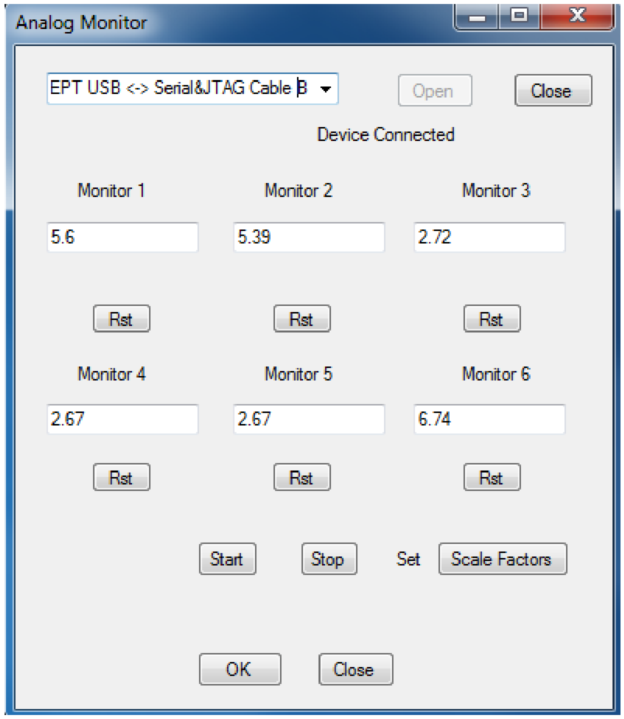
To test our Analog Monitor project, just click on the Start button. As soon as the device connects, the data from the Arduino will appear in the received data textBox.



Turn on all six of the 5VDC Power Supplies. Click on the “Set Scale Factors” button.



Type the scale factor for each Monitor textbox in the corresponding ScaleFactor textbox. The scale factor is 5V/1024Counts. Our scale factor is 0.0048828 Volts/Counts.



And that’s all there is to the Analog Monitor Project. It’s up to the user to use this project as a base to create much larger projects. You can easily make a volt meter using this project by turning off the Random number generator in the Arduino and reading the Analog Pins. Also, reformat the textBox display that it shows in decimal instead of the Hexadecimal display.