RENSSELAER MECHATRONICS

Communication: Sending Data

Overview:

External mode in Simulink allows data to be sent and received from the target board. This communication protocol has significant overhead which limits how fast data can be transferred. For example an Arduino Mega in external mode the maximum sampling rate is around 30Hz with 2015a or earlier and up to 1Khz with later versions of MATLAB. To obtain information at a faster rate the data can be send directly from the target without using external mode.

This lab explores sending data with Simulink using both built in blocks, system object blocks and with the Arduino IDE.

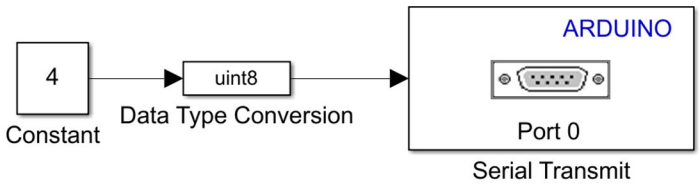
Part 1: Sending 8 bit data with Simulink

Objectives:

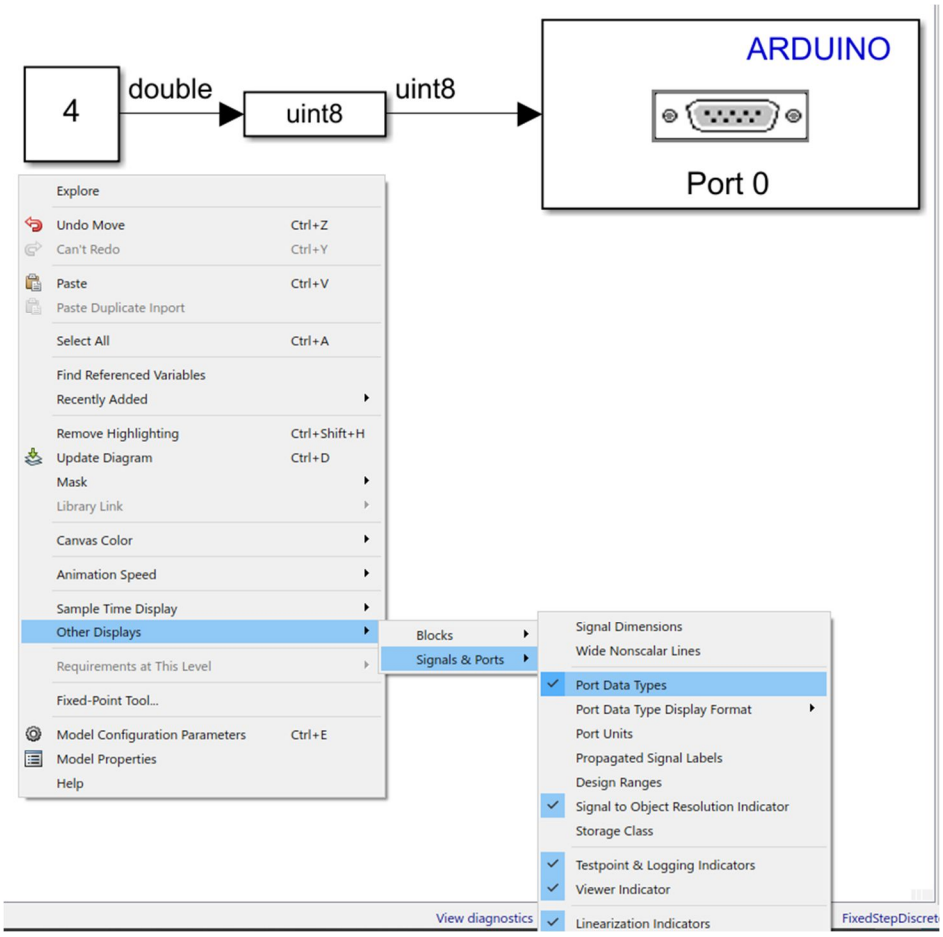
- Send 8 bit data over the serial link using the supported Simulink blocks

Simulink Model:

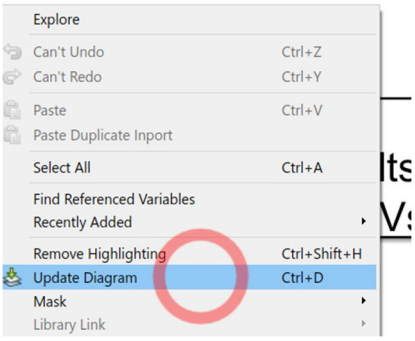
- Build the Simulink diagram form a "Constant", "Data Type Conversion" and a "Serial Transmit" block. Be sure to use the blinking LED Simulink diagram and create this new one from that one.



- The Simulink Arduino library block "Serial Transmit" can be used to send single bytes at a time. To see this right-click in the main windows and select "Other Displays – Signals & Ports – Port Data Types":

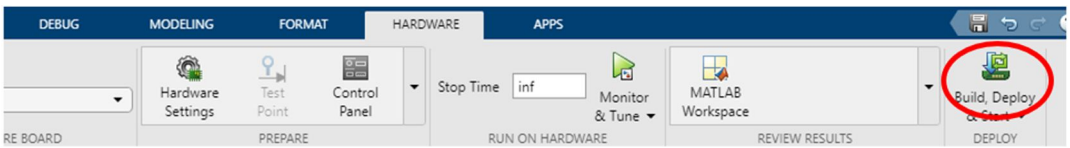


- Press “Control+D” to update the diagram see the data types, right-click in the diagram to Update the Diagram:

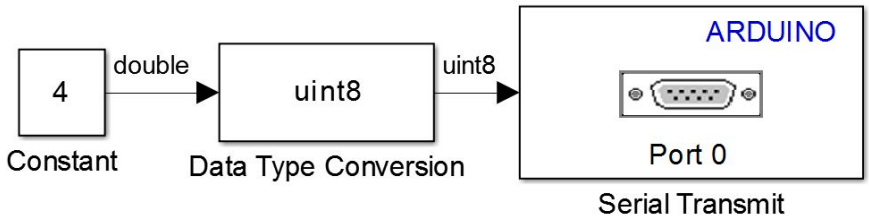


The input data type for a Serial Transmit is uint8 (a single byte, 8 bits, of data). This means that data must be converted to unit8 before sending across the serial line with this block.

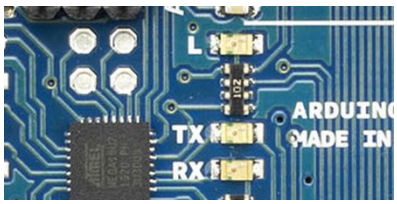
- Build and run the following Simulink diagram.
  - Click the the ‘Build, Deploy & Start’ button:



- The baud rates for the ports are set in the Configuration Parameters in the Run On Target Hardware tab – by default they are 9600
- Set the sample time of the simulation to .1 second – this means it will send the number 4 in binary every .1 seconds through Port 0 (which is the USB cable)



- After the code is downloaded you should see the TX or RX LED blinking, or remain lit, indicating data is being sent across the serial line:



Reading the Data with MATLAB:

Create an m-file with the following code. Use the COM port of your device. This code will open the com port and store the results in the variable d1:

```
% Read from Serial port 14:
s = serial('COM14');
set(s,'ByteOrder', 'bigEndian','BaudRate', 9600);
% Open Serial Port:
fopen(s);
% Read 30 data points
d1=(fread(s, 30, 'uint8'))'

% Close the serial port:
newobjs=instrfindall;
fclose(newobjs);
```

The output on the MATLAB command line should be:

```
dl =

  Columns 1 through 21

     4     4     4     4     4     4     4     4     4     4

  Columns 22 through 30

     4     4     4     4     4     4     4     4     4
```

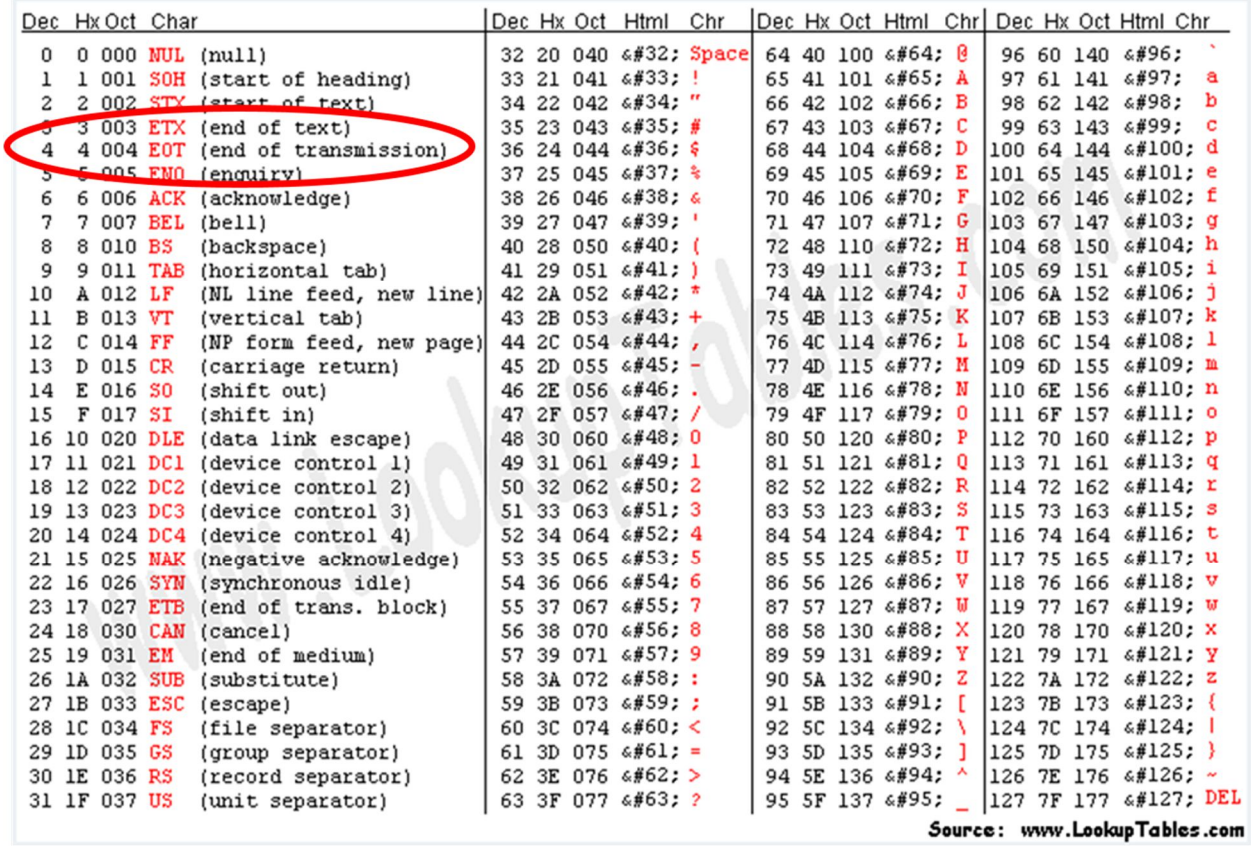
To display the ASCII equivalent characters, or the binary form of ones and zeros:

```
% Read from Serial port:
s = serial('COM10');
set(s,'ByteOrder', 'bigEndian','BaudRate', 9600);
% Open Serial Port:
fopen(s);
% Read 30 data points
dl=(fread(s, 30, 'uint8'))' % display data
dl_characters=char(dl)                    % display data as characters
dl_binary=dec2bin(dl)                  % display ones and zeros

% Close the serial port:
newobjs=instrfindall;
fclose(newobjs);
```

The result

```
dl_characters =

    '□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□'
```

You notice it will display the characters that the bytes represent instead of the numerical binary values.
The characters represented by a byte can be found from a Ascii character table:



Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Here we can see that the number 4 represents the represents “EOT” character which we see displayed as □□□□ Note the same data is always being sent, we are simply changing how it is displayed on the screen – as a character “EOT”, or as the numerical binary data 4.

You can also have MATLAB show the actual ones and zeros corresponding to the number 4:

```
dl_binary =

  30×3 char array

    '100'
    '100'
```

This is explained in a more detail in the section “Reading the Data with RealTerm”

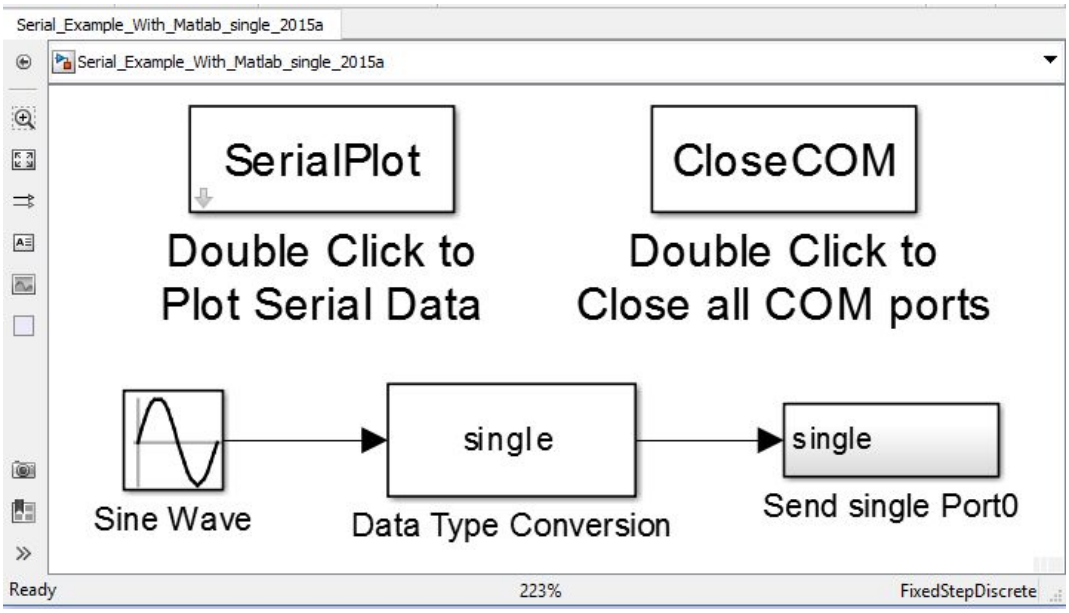
Part 2: Sending and Receiving Data with RASPlib

Objectives:

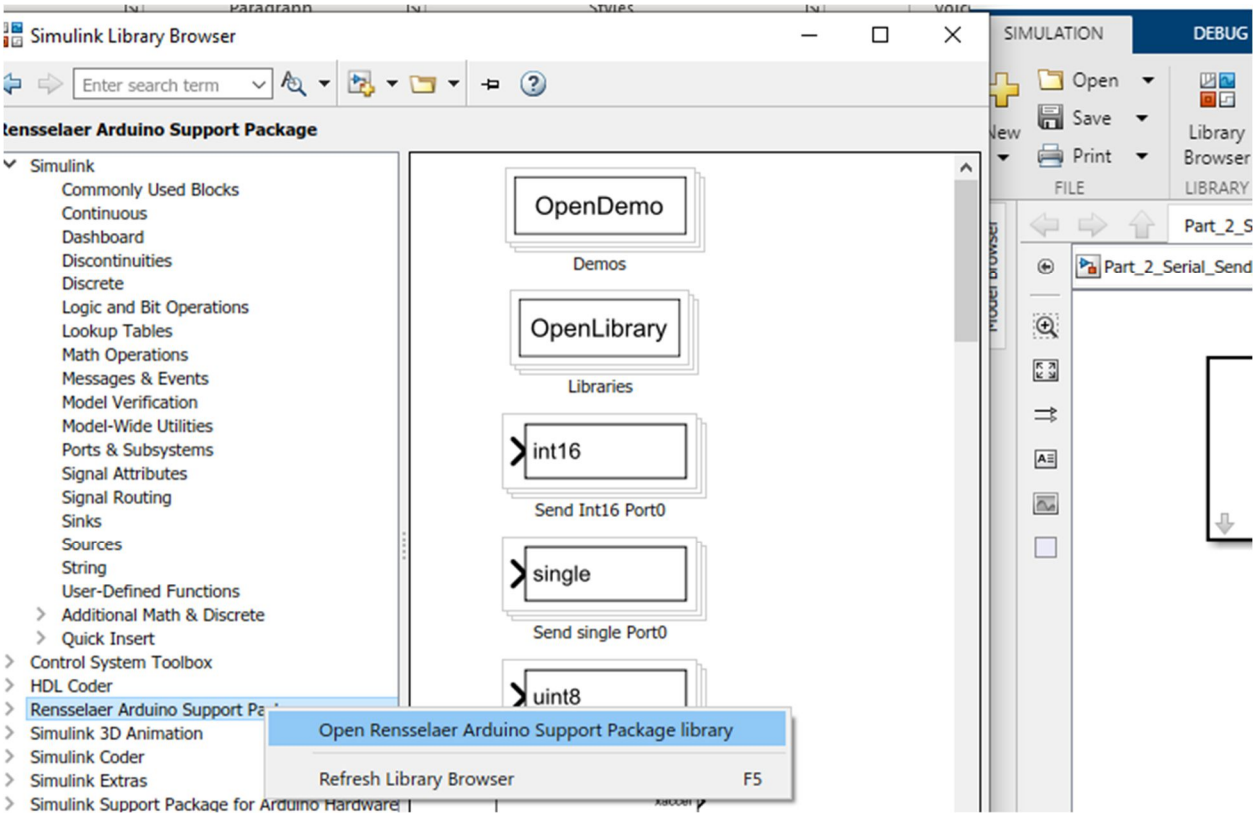
- Use RASPlib to send, plot and store data. Data can be sent and received faster than external mode. The exact number of bytes sent each time step is specified.

Simulink Model:

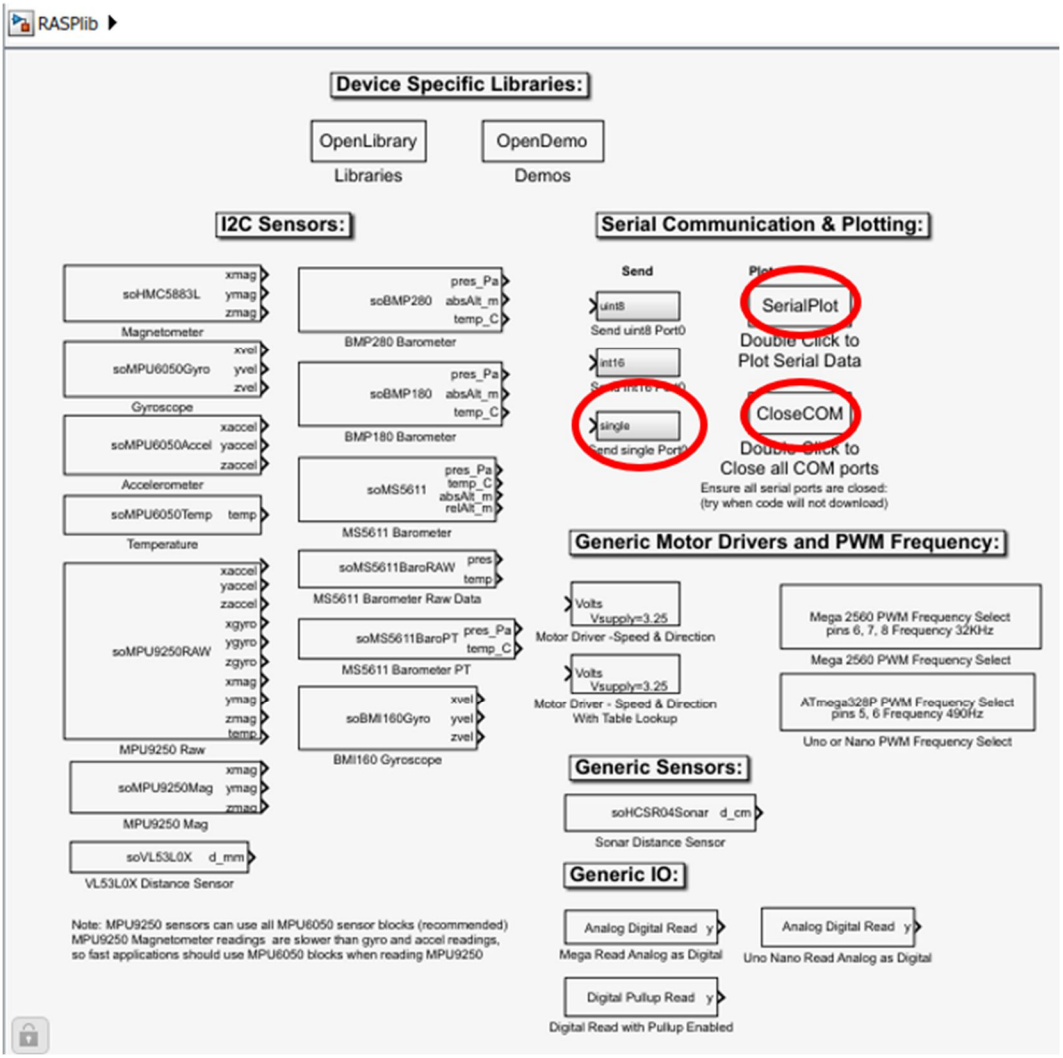
- Build the following Simulink diagram: (note if your Simulink diagram does not show the block names by default you can right click the block and select ‘format’, ‘show block name’, ‘on’.)



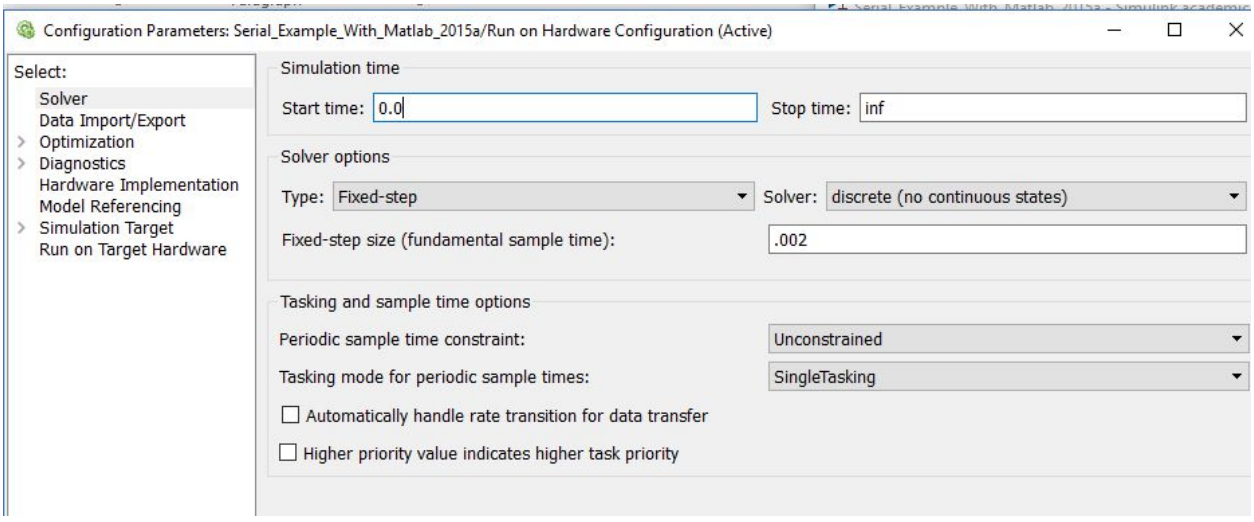
SerialPlot, CloseCOM, and “Send single Port0” are all obtained from RASPlib. Open Rasplib from the “Simulation” tab and select “Library Browser” then right click “Rensselaer Arduino Support Package Library”:



Then drag the blocks to you diagram:

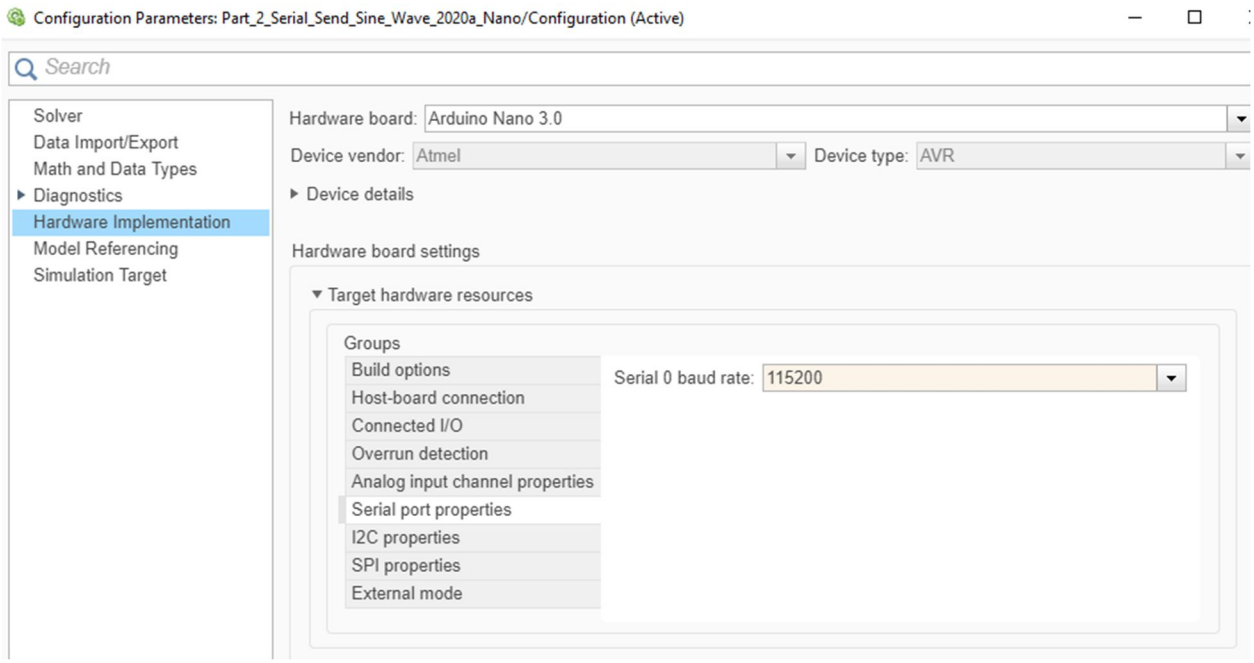


Use solver settings:

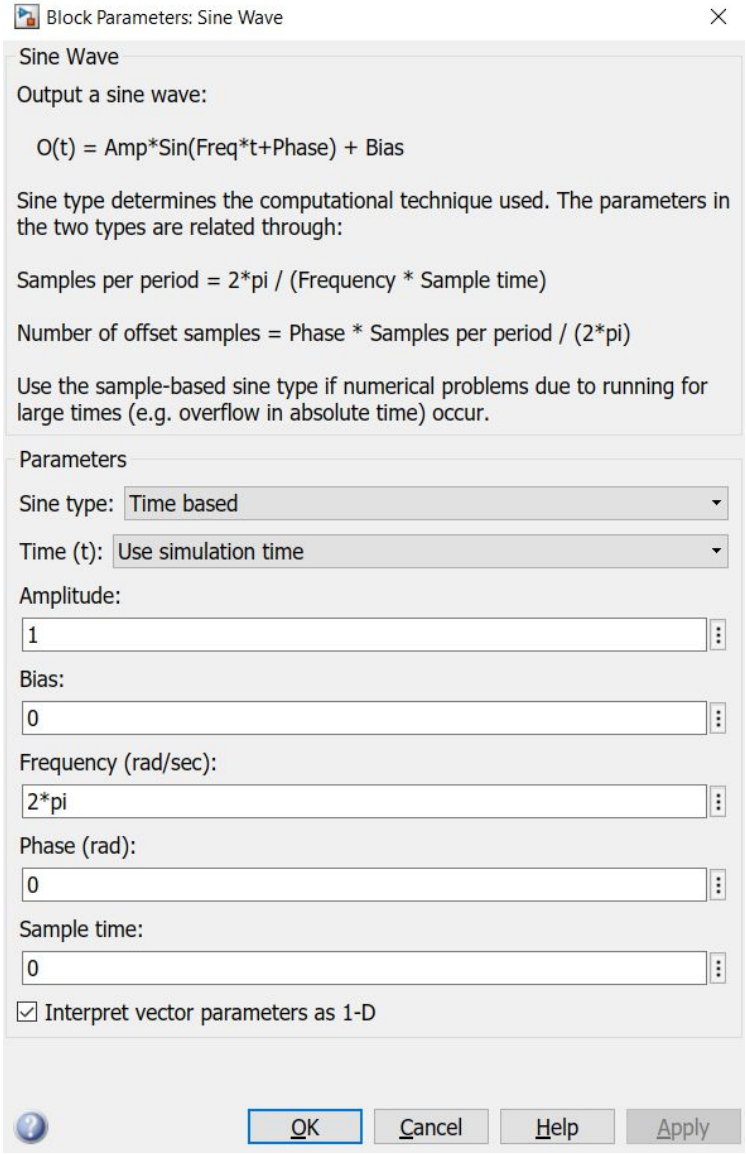


BAUD Rate Calculation

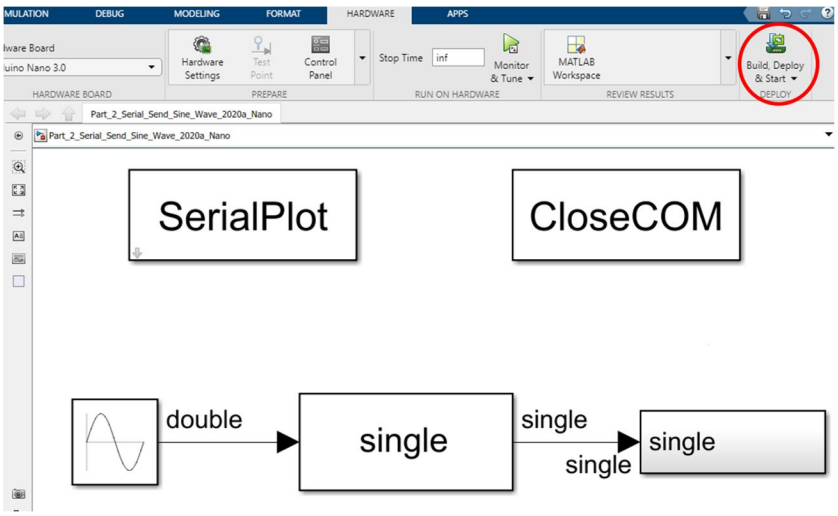
The default setting for the BAUD rate is 9600. In the above case the sample time is .002 second, and we are sending a single which is 4 bytes. The amount of bits (8 bites in a byte) per second is then 4*8/.002 = 16000 bits per second. This means the minimum BAUD rate for a single data channel at .002 is 1600. Choose 115200, which is more than fast enough. Rates faster than 115200 seem to start having hardware issues and seem to be less reliable. Access this menu form the “Hardware” Tab then “Hardware Settings”



And a sine wave with magnitude 1 and frequency 2*pi:



Next download the code to the hardware:

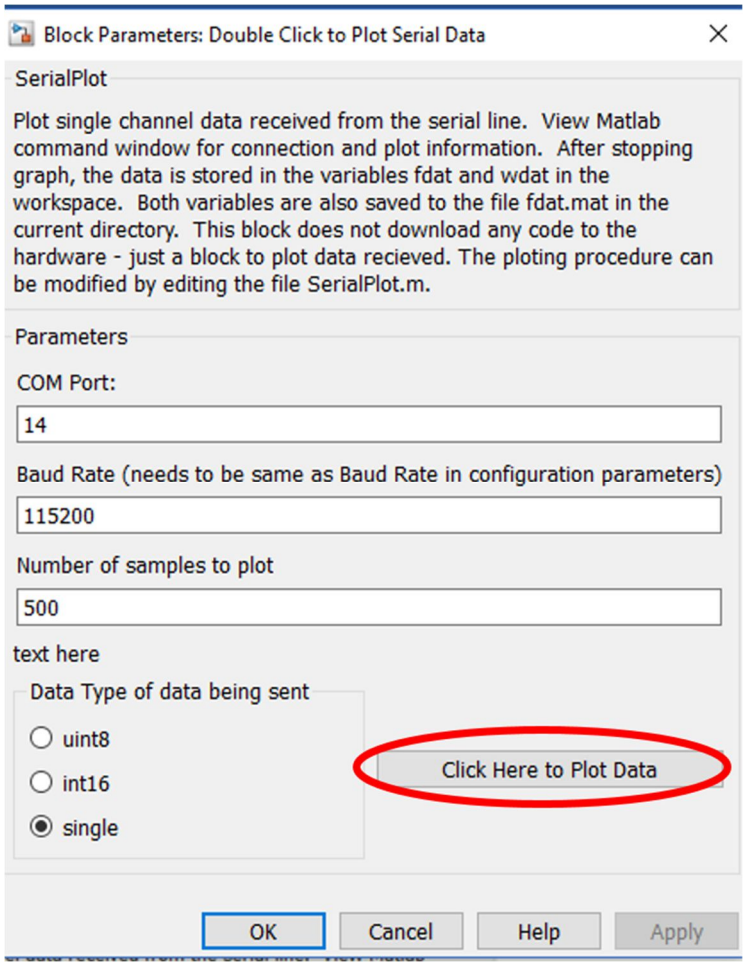


Note that the “Build, Deploy & Start” button downloads the code to the hardware only. After it downloads it will only execute the code you specify, in this case sending data from a sine wave to port 0 as a “single” floating point number (4 bytes).

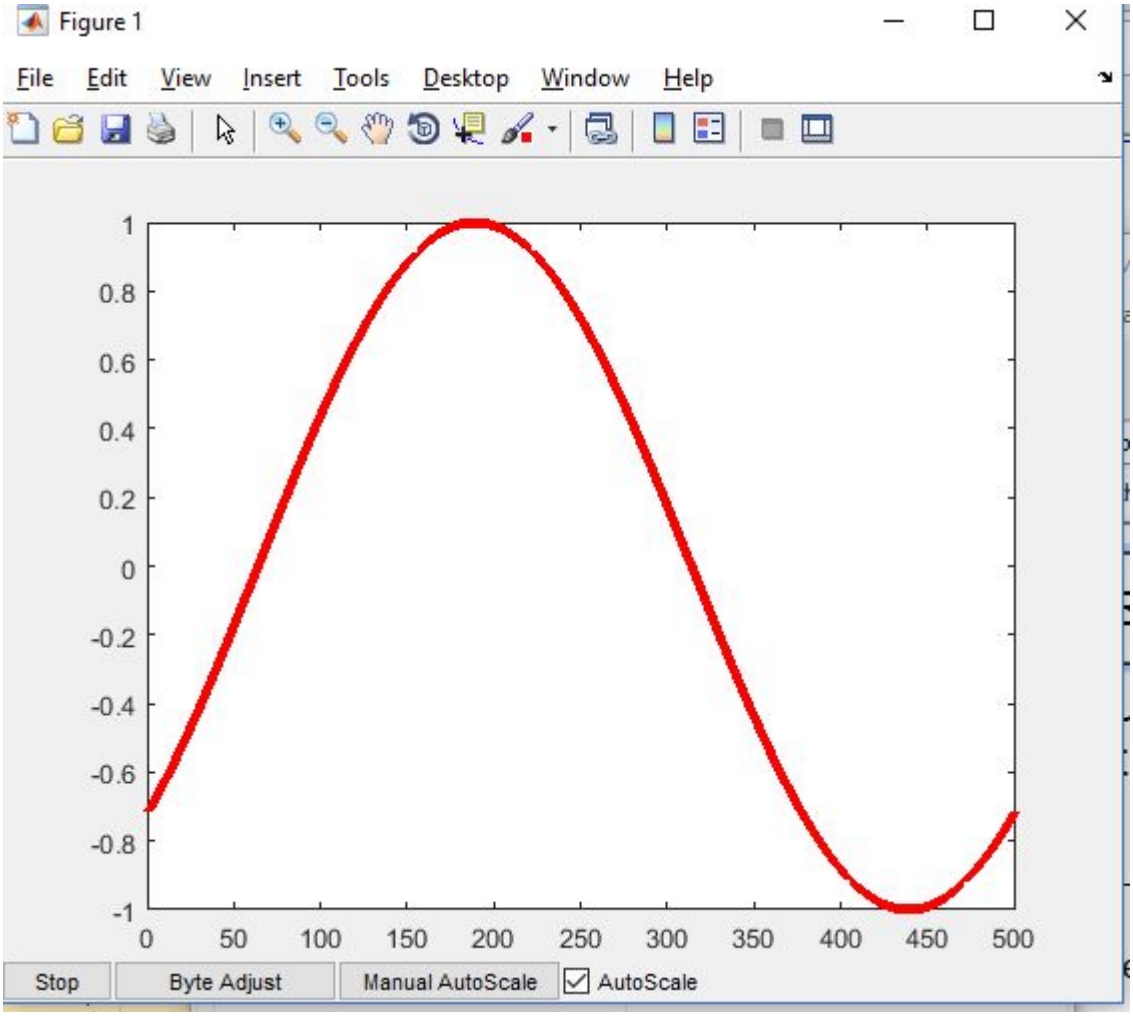
After the code has been downloaded the “Tx” light on the board should light up indicating data is being sent to the computer.

- To capture and plot the data double click the “SerialPlot” block and set the following parameters. Be sure to use your COM port and the BAUD rate as specified in the configuration parameters.

- Then click “Click Here to Plot Data”



You should observe a sine wave of frequency 2*pi rad/sec – which should repeat every second:



- Click “Stop” to stop recording data.
- The data is stored in file “dat.mat” in the current directory
- The complete data is stored in the fdat variable and the last window data in the wdata variable. You can then easily plot the stored data:

```
>> plot(fdat)
>> plot(wdat)
```

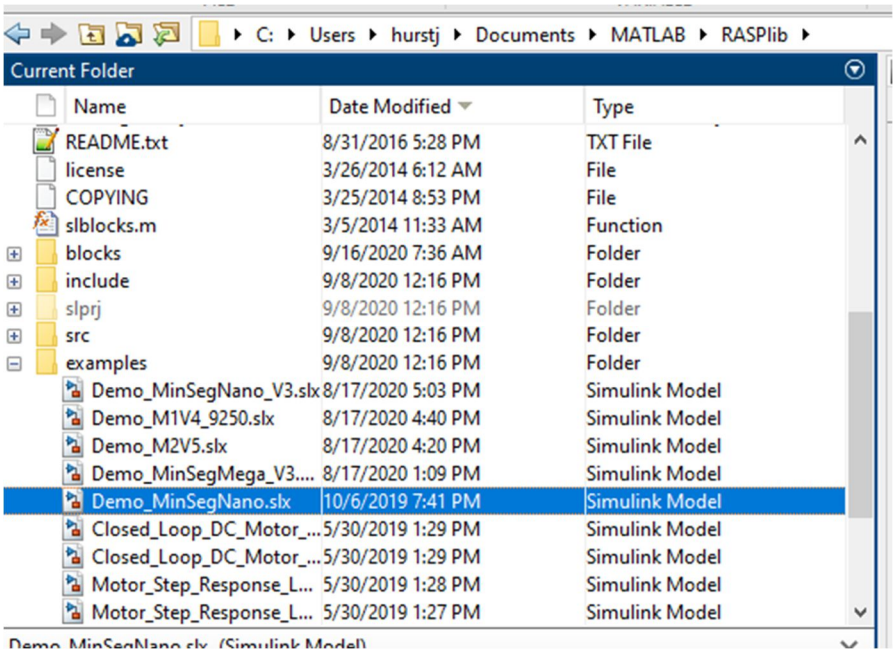
There are 3 possible data types you might want to send

Type	Bytes	Range
uint8	1	0 to 255
int16	2	-32768 to 32767
single	4	-1.401298E-45 to 1.401298E-45

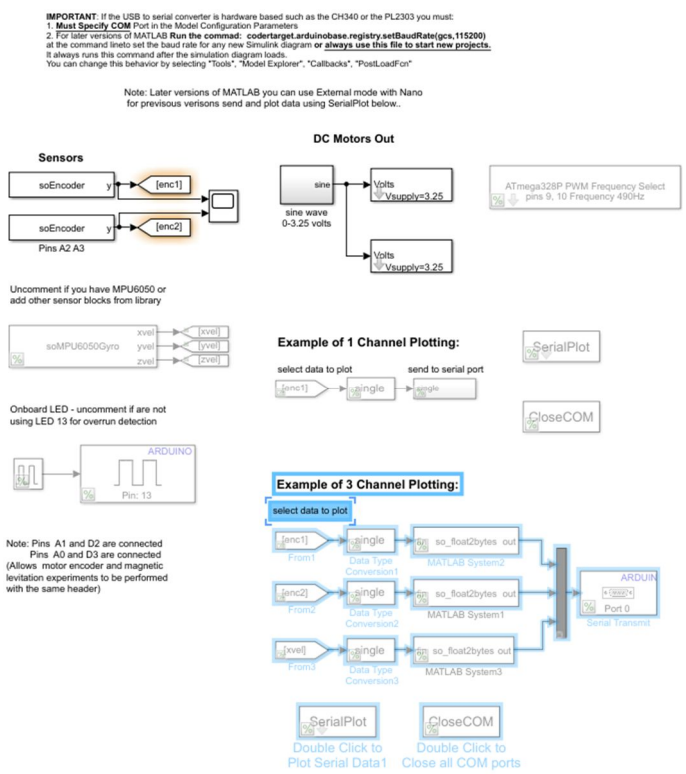
In general single should be used, but if data is needed faster other types can be used as long as the data is scaled to within the range of the data type.

Sending Multiple Data channels with RASPLib

Open the example “Demo_MinSegNano.slx” located in the RASPlib\examples folder:

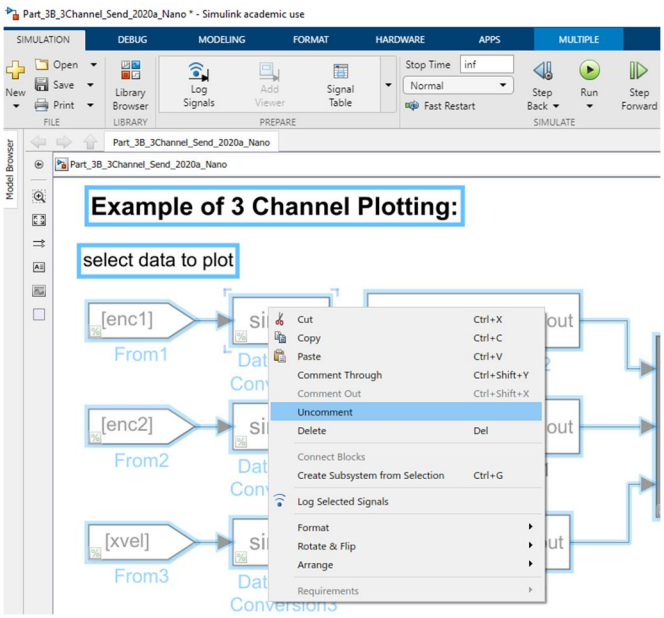


Copy the contents of “Example of 3 Channel plotting”

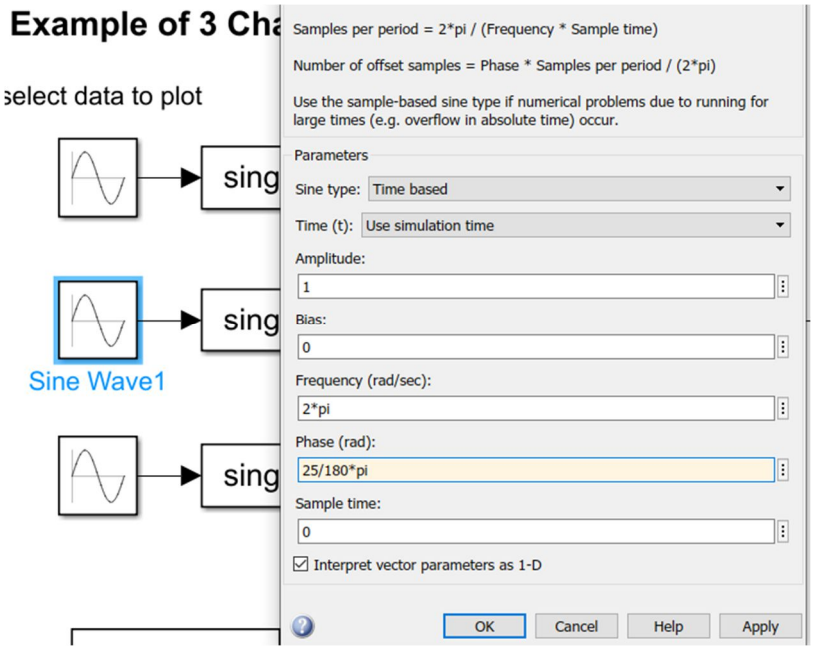


Paste these into a current Simulink Project for the Arduino, and save the new file with a new name in a an appropriate directory.

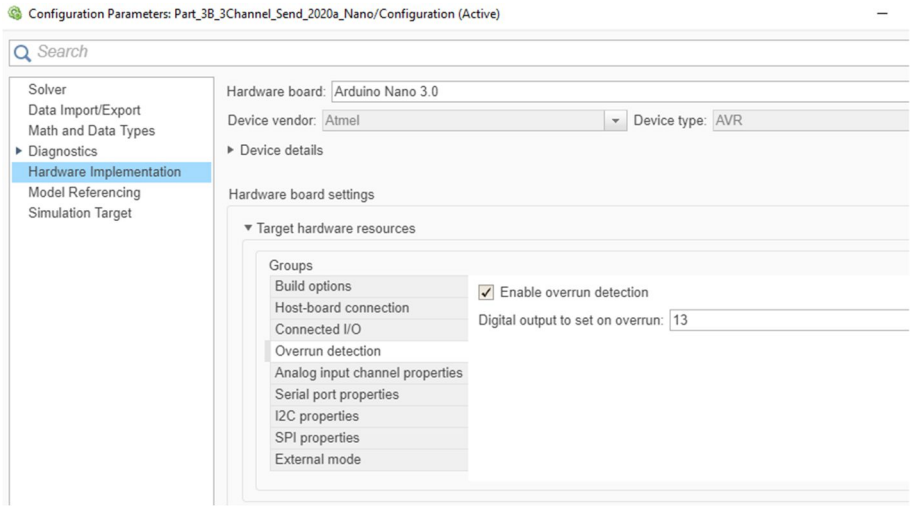
Select all the code and righ-click it to uncomment it:



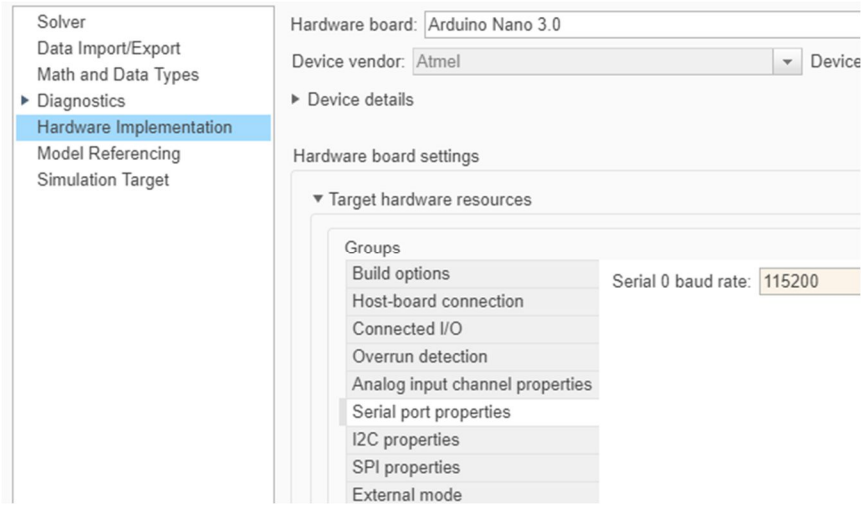
Next modify the 3 inputs to be sine waves, each shifted by 25 degrees from the previous:



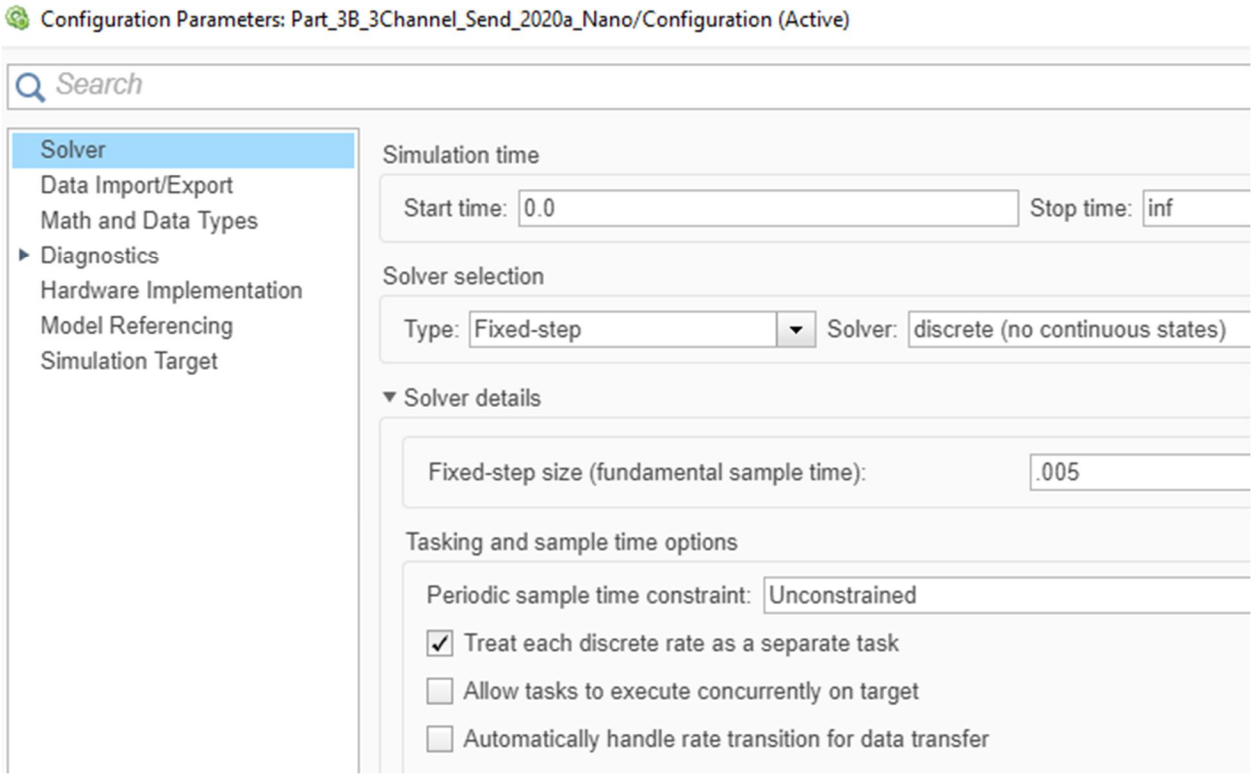
Make sure overrun detection is on:



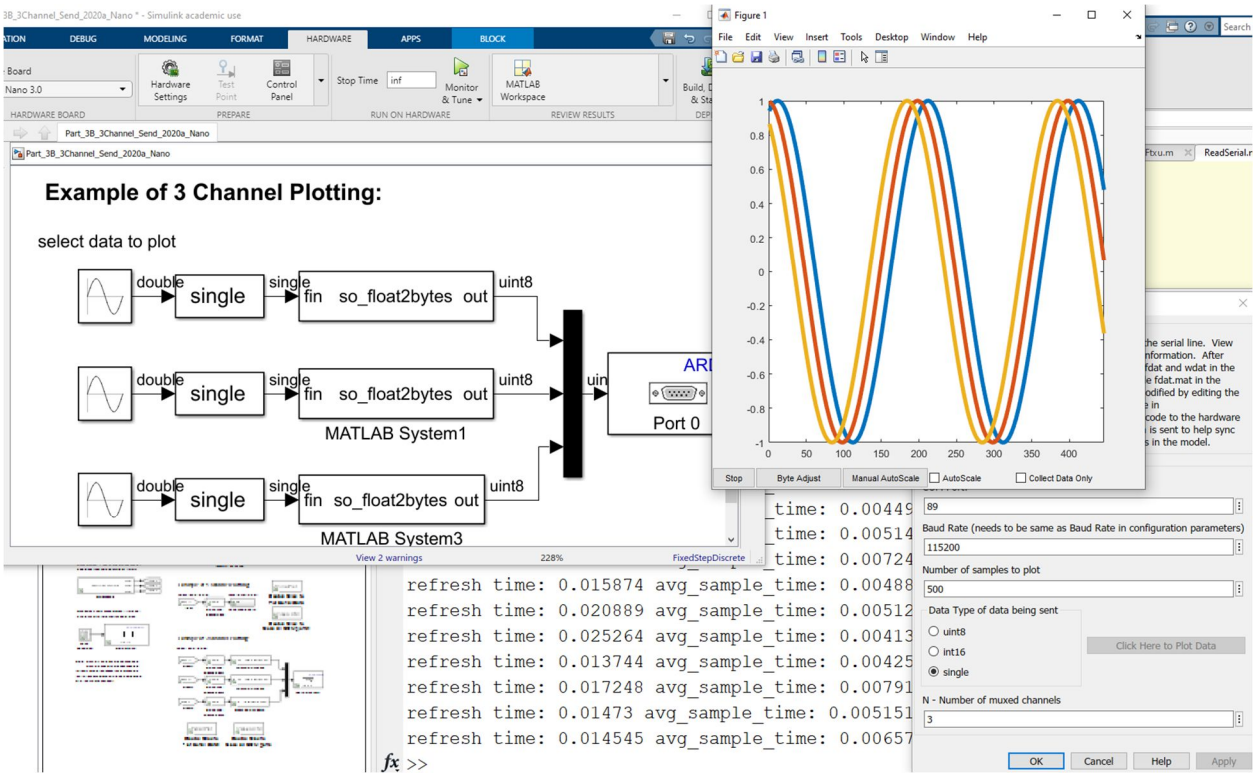
Baud rate is set to 115200



And the sample time is set to 5ms:

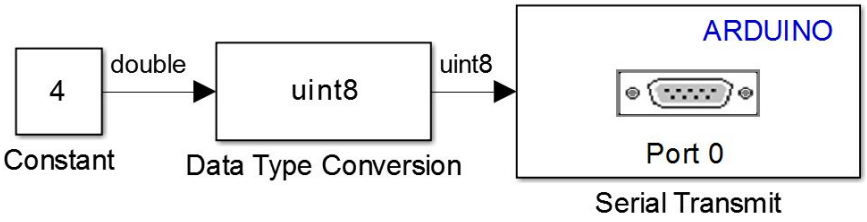


Download to the board and use Serial Plot to observe the results:

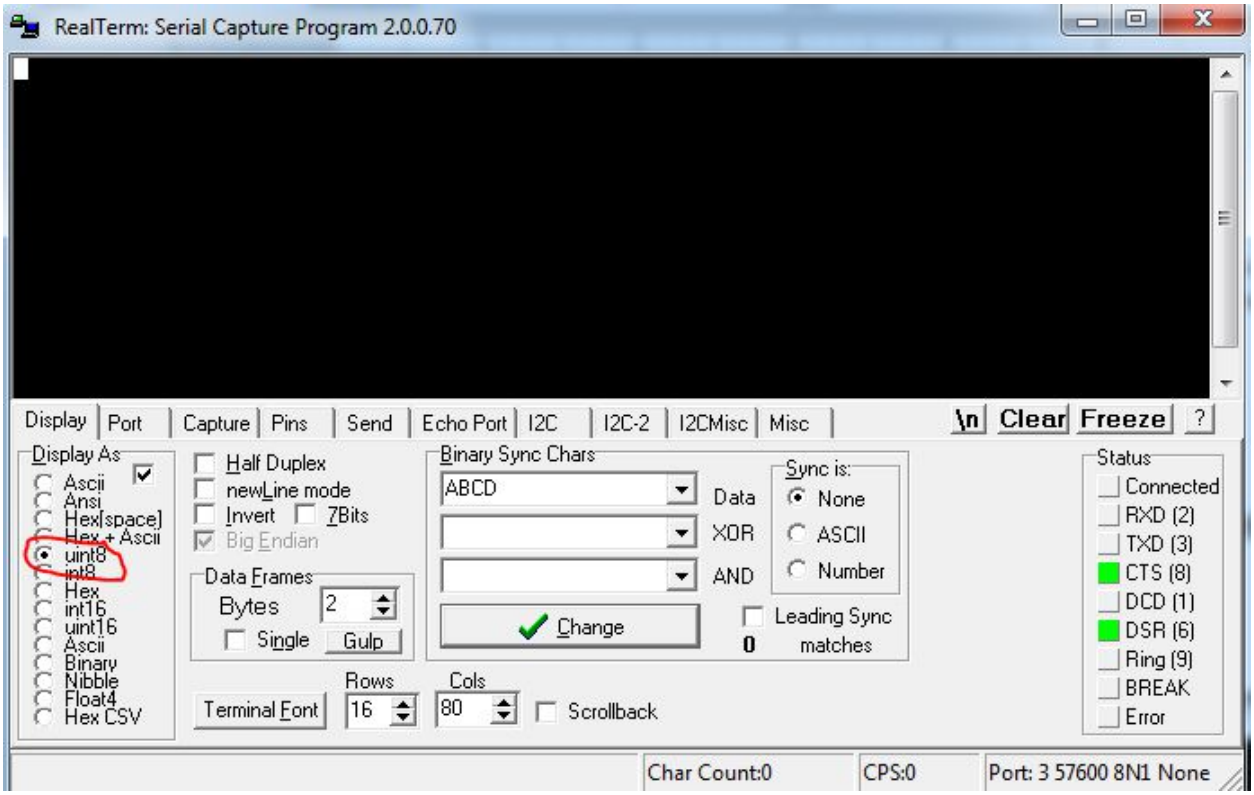


Part 3: Reading the Data with RealTerm (optional)

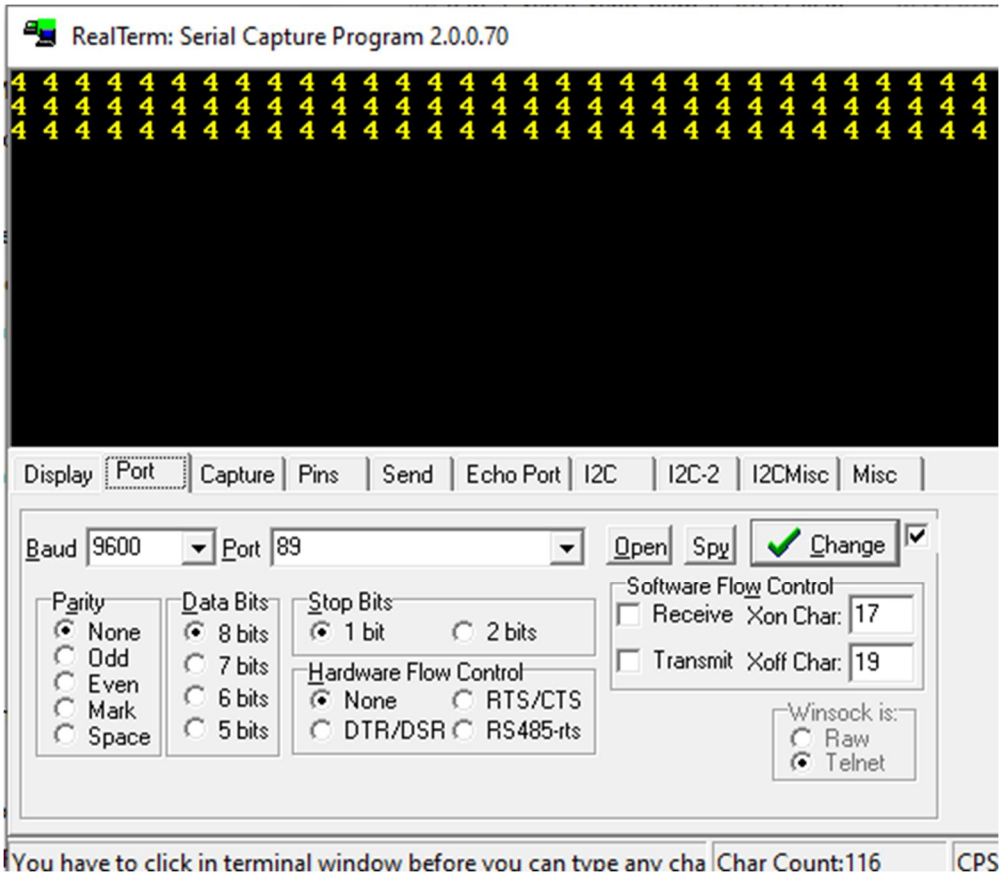
Another way to obtain data is RealTerm – although any serial terminal program will work. First download the following code to the Arduino:



After installing RealTerm open it in administrator mode.

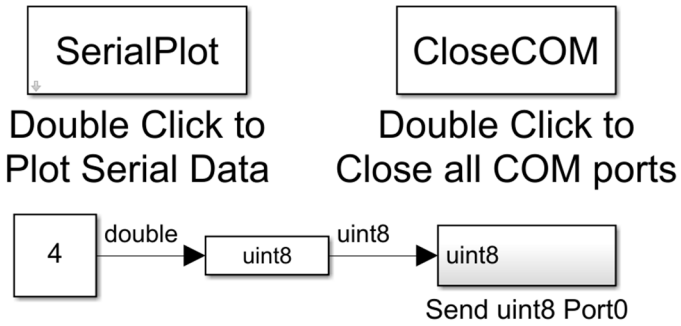


- On the left select “uint8”. This indicates to realterm that the data type to expect is uint8 and it will display the results appropriately.
- Click the “port” tab, change the baud rate to 9600
- select the serial port of your hardware
- If the Open tab is depressed (as in the figure below) click it once to “close” the port, and again to “open” it. It should then start displaying data:

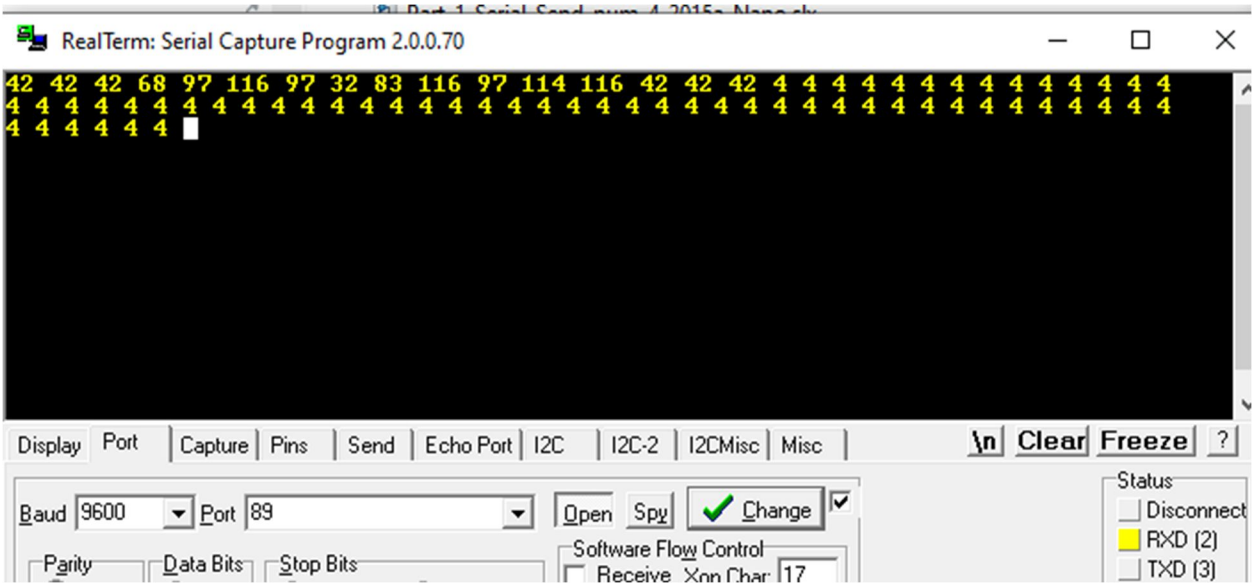


By specifying “uint8” RealTerm knows the data type so it can display it correctly.

Next modify the first Simulink diagram to use the RASPLib block to send the number 4.

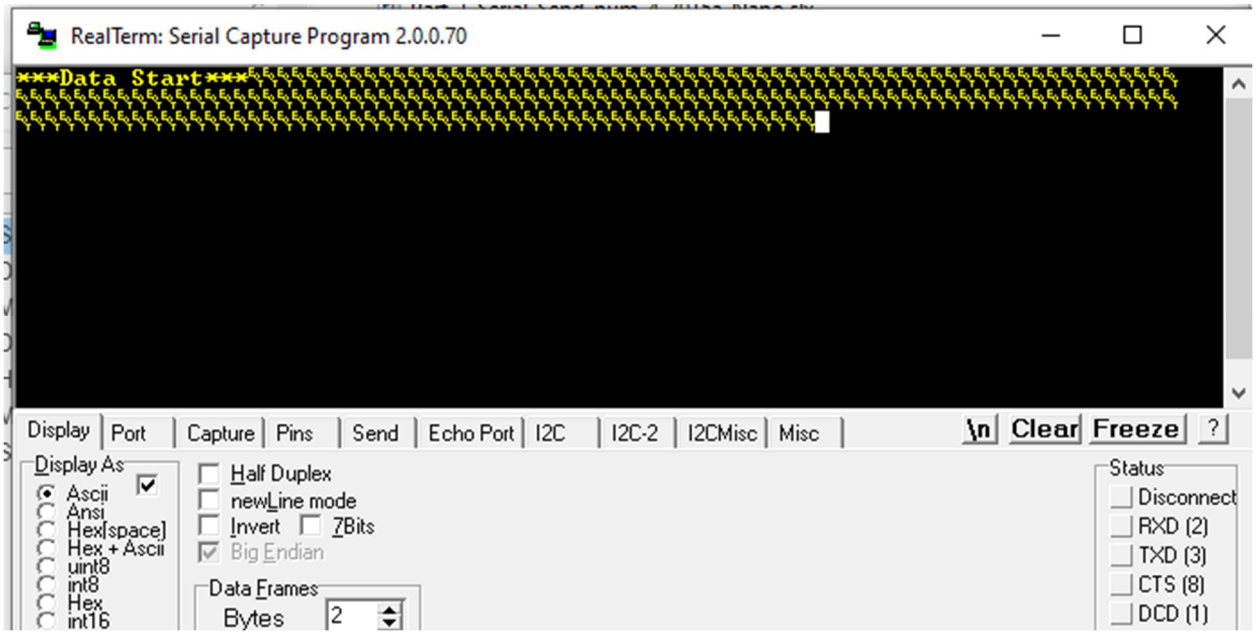


Use the same settings and open RealTerm: (sovler of .05 seconds, Baud rate of 9600):



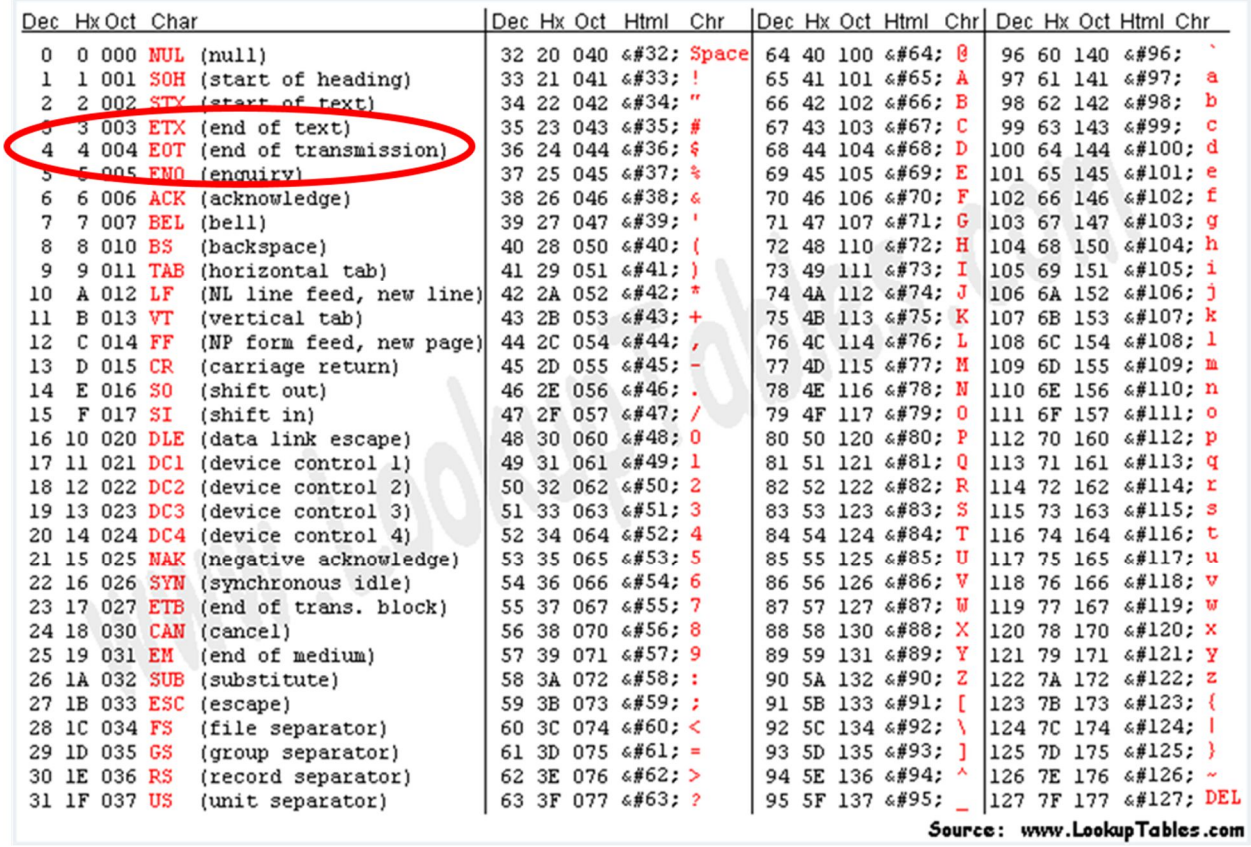
Notice there are a bunch of numbers befor our data of fours “4 4 4 4”.

Change the “Display As” to “Ascii” and open the port again:



The program sends the message “***Data Start***” before sending data. This is so that the program that receives and plots that data can synchronize it by reading the “***Data Start***” sequence before plotting the data!

You notice it will display the characters that the bytes represent instead of the numerical binary values. The characters represented by a bye can be found from a Ascii character table:



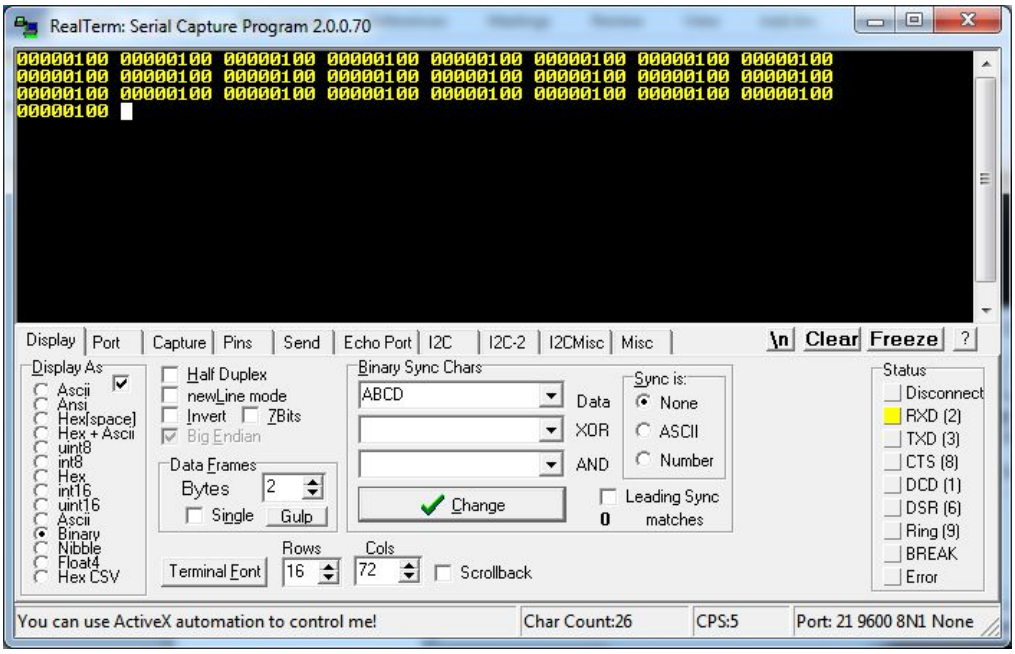
Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Here we can see that the number 4 represents the represents “EOT” character which we see displayed. Note the same data is always being sent, we are simply changing how it is displayed on the screen – as a character “EOT”, or as the numerical binary data 4 – but they ones and zeros are always the same.

To see the actual ones and zeros

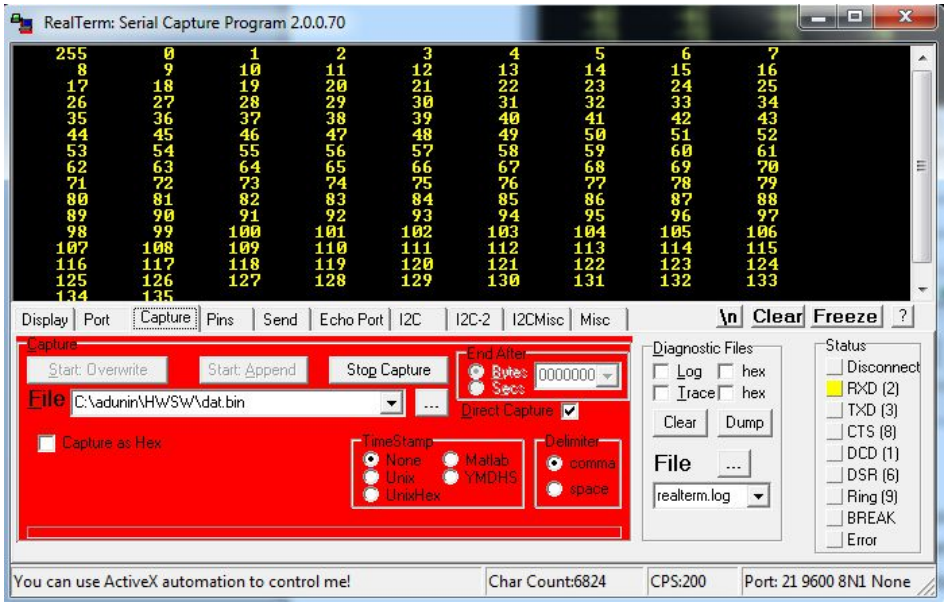
- go back to the Display tab and select Binary



Now the actual binary representation of the data is seen: 00000100 is the number 4, or the character "EOT", but the ones and zeros are always the same.

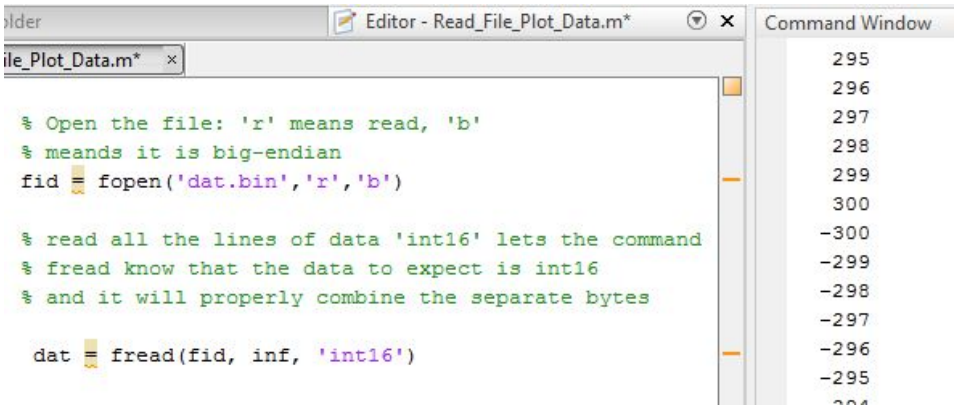
Writing the data to a file with RealTerm:

- Open RealTerm, set the baud rate and port, and connect
- Click the "Capture" tab
    - Enter the location and filename you want to store the data (your current Matlab directory). Since the data is in binary the filename should end in .bin to reflect this
    - Click the "Start Overwrite" button to begin writing data to the file



Reading the data file with Matlab:

Write the following M-file to open the file and read the bytes in the appropriate format:



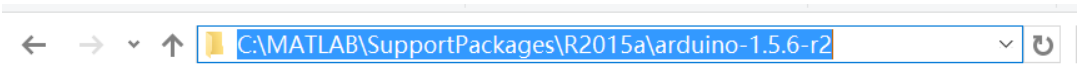
Part 4: Sending data with the Arduino IDE (optional)

Objectives:

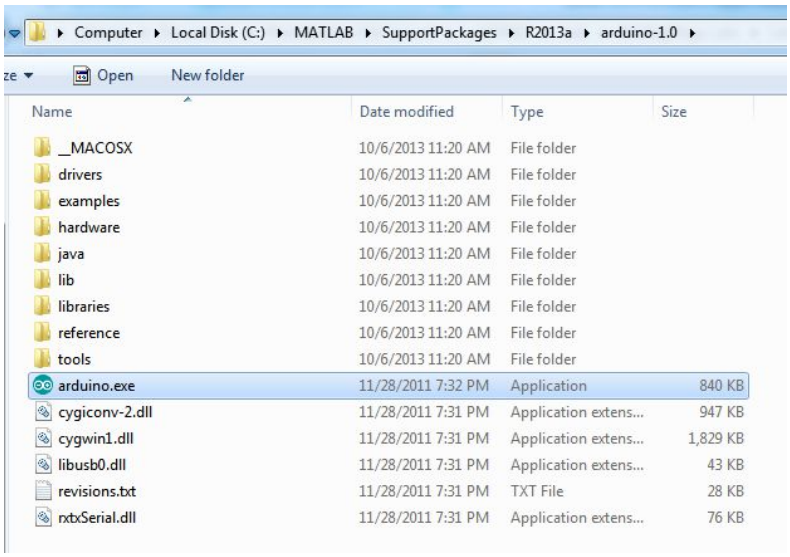
- Use the Arduino IDE to send ascii encoded data and binary data

Arduino Code:

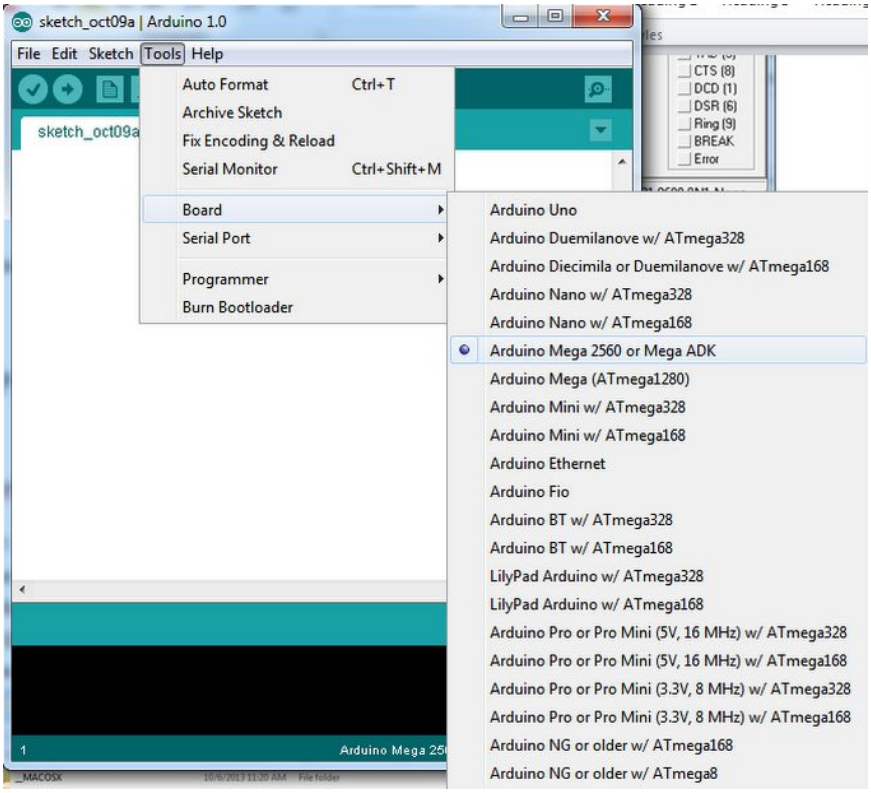
- Matlab uses the Arduino IDE and Arduino libraries. When it installs the Arduino Simulink blocks it installs the Arduino IDE typically in this location
    - C:\MATLAB\SupportPackages\R2013a(R2014a)\arduino-1.0(arduino-1.0.5)
    - C:\MATLAB\SupportPackages\R2015a\arduino-1.5.6-r2 (You can copy this path and directly paste it in “This computer” to find “arduino.exe”)
        - 2015a has both a arduino-1.0 folder an arduino-1.5 folder – either will work but 1.5 is the latest version so use this.



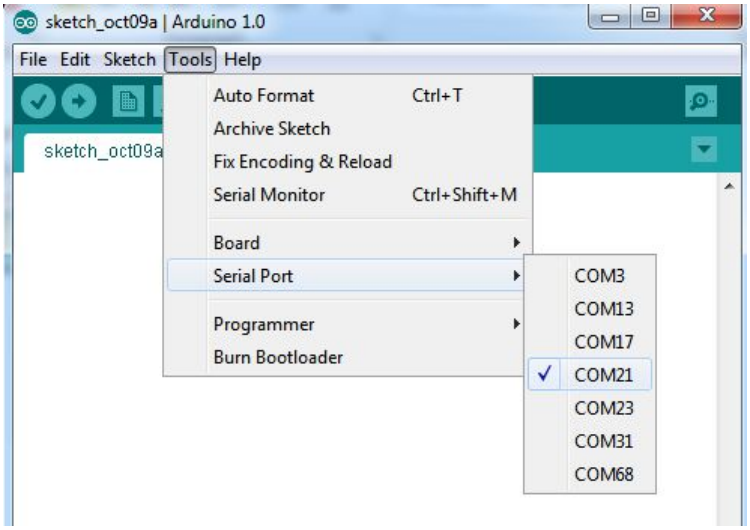
    - The Arduino IDE can be opened from here:



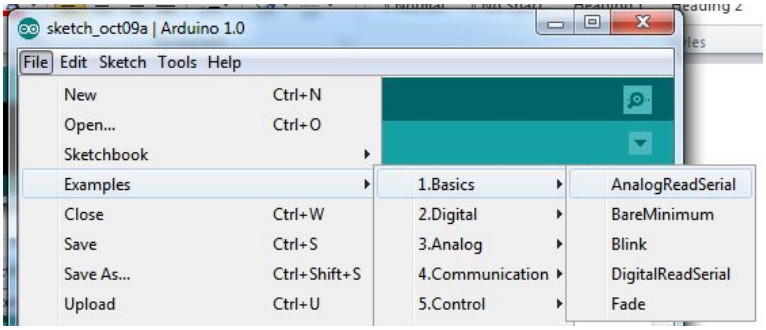
- Select your target board:



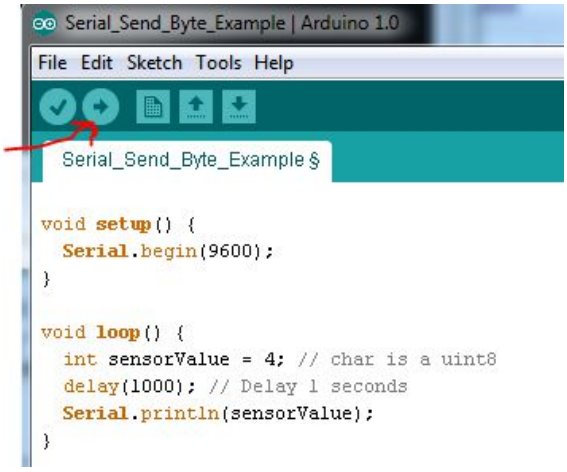
- Select the serial port:



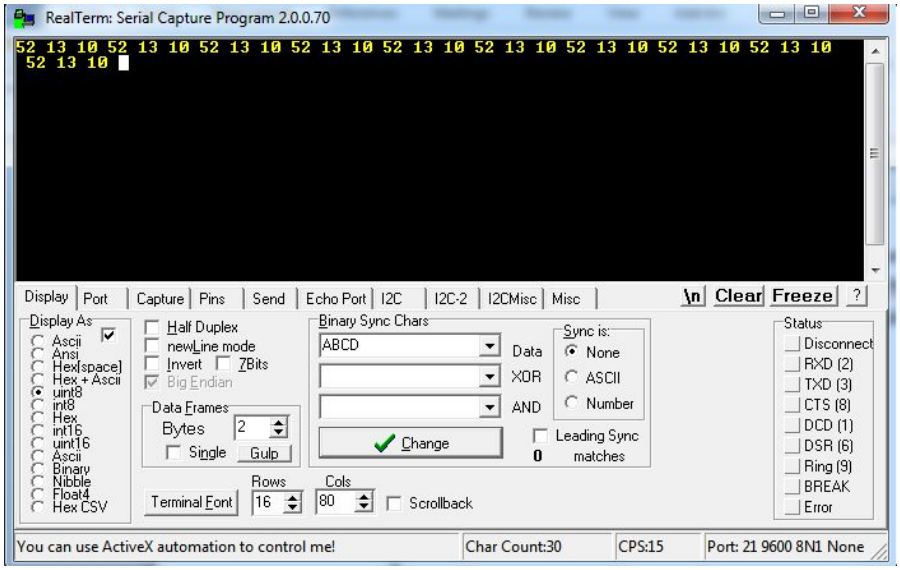
- Open a basic serial example:



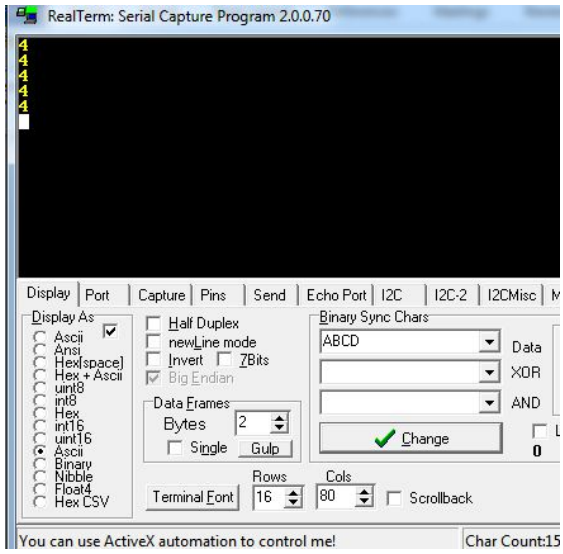
- **Modify** the code to send only the number 4:
    - Download the code to the board with the Right arrow
    - Note – you must make sure the serial port from RealTerm is closed – it cannot download code when the serial port is open in another application



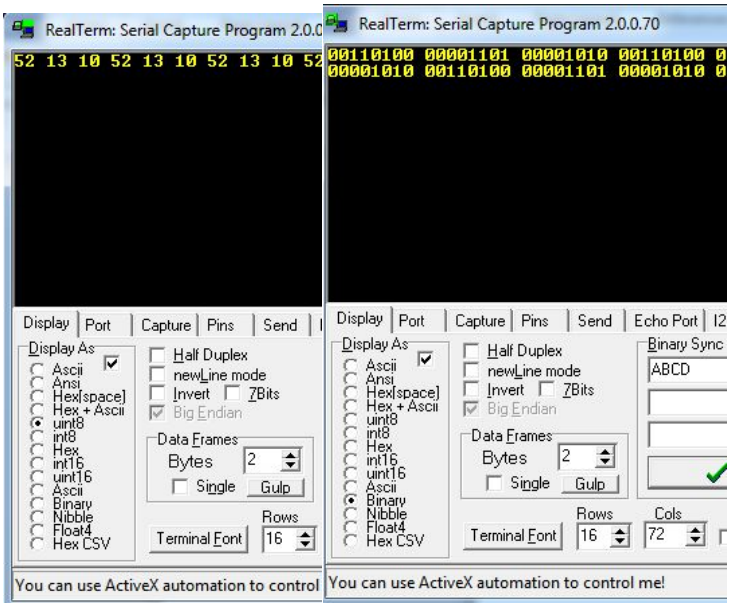
    - Open the terminal program to view



The data is not as expected. Now click on Ascii for the Display as format



The display shows 4. When the 'Serial.println()' command is used the data is encoded to human readable ASCII characters. The data (4) is encoded to the character '4' which is represented in decimal as 52 (101010). In addition each 4 is written on a new line which is a carriage return followed by a new line 13 (00001101) and 10 (00001010):



If you want to write the data in binary (that is 4 as 0000100) use the Serial.Write command.

Questions

A analog sensor records a vlaue 16 (the result of the Analog to Digital conversion). You want to send this data from the microprocessor to your computer.

- How many bytes does it take to send this data in binary format?
    - What is the binary (ones and zeros) representaiton of this data?
- How many bytes does it take to send this data ASCII encoded?
    - What is the binary (ones and zeros) representation of the ASCII encoded data?

Now the sensors reads 32768.

- How many bytes does it take to send this data in binary format?
    - What is the binary (ones and zeros) representaiton of this data?
- How many bytes does it take to send this data ASCII encoded?
    - What is the binary (ones and zeros) representation of the ASCII encoded data?

- Which of these formats would be “fastest” to send?