Serial Communication

- Exam
- Project 5 code reviews

Questions?

Input/Output Systems

Processor needs to communicate with other devices:

- Receive signals from sensors
- Send commands to actuators
- Or both (e.g., disks, audio, video devices, other processors)

I/O Systems

Communication can happen in a variety of ways:

- Binary parallel signal
- Analog
- Serial signals

An Example: SICK Laser Range Finder

- Laser is scanned horizontally
- Using phase information, can infer the distance to the nearest obstacle
- Resolution: ~.5 degrees, 1 cm
- Can handle full 180 degrees at 20 Hz

Serial Communication

- Communicate a set of bytes using a single signal line
- We do this by sending one bit at a time:
  - The value of the first bit determines the state of a signal line for a specified period of time
  - Then, the value of the 2^{nd} bit is used
  - Etc.

Serial Experiment…

Serial Communication

The sender and receiver must have some way of agreeing on when a specific bit is being sent

- Some cases: the sender will also send a clock signal (on a separate line)
- Other cases: each side has a clock to tell it when to write/read a bit
  - The sender/receiver must first synchronize their clocks before transfer begins

Asynchronous Serial Communication

- The sender and receiver have their own clocks, which they do not share
- This reduces the number of signal lines

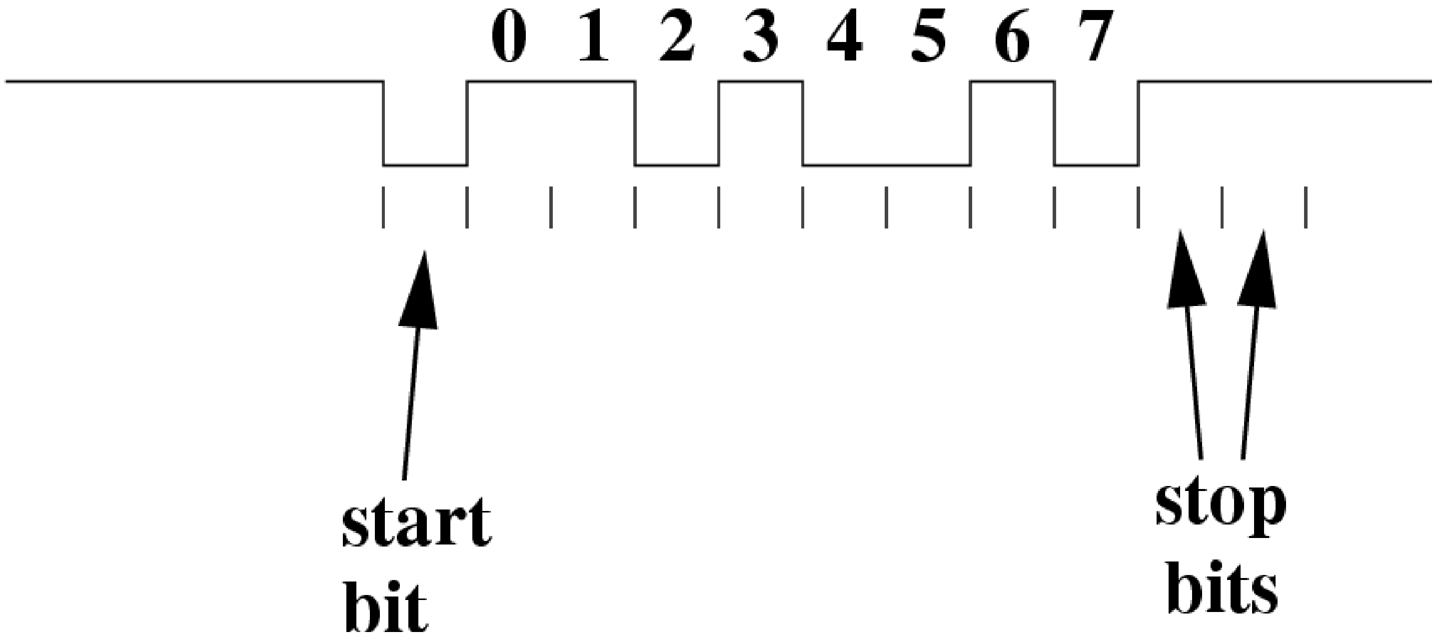
But: we still need some way to agree that data is valid. How?

Asynchronous Serial Communication

How can the two sides agree that the data is valid?

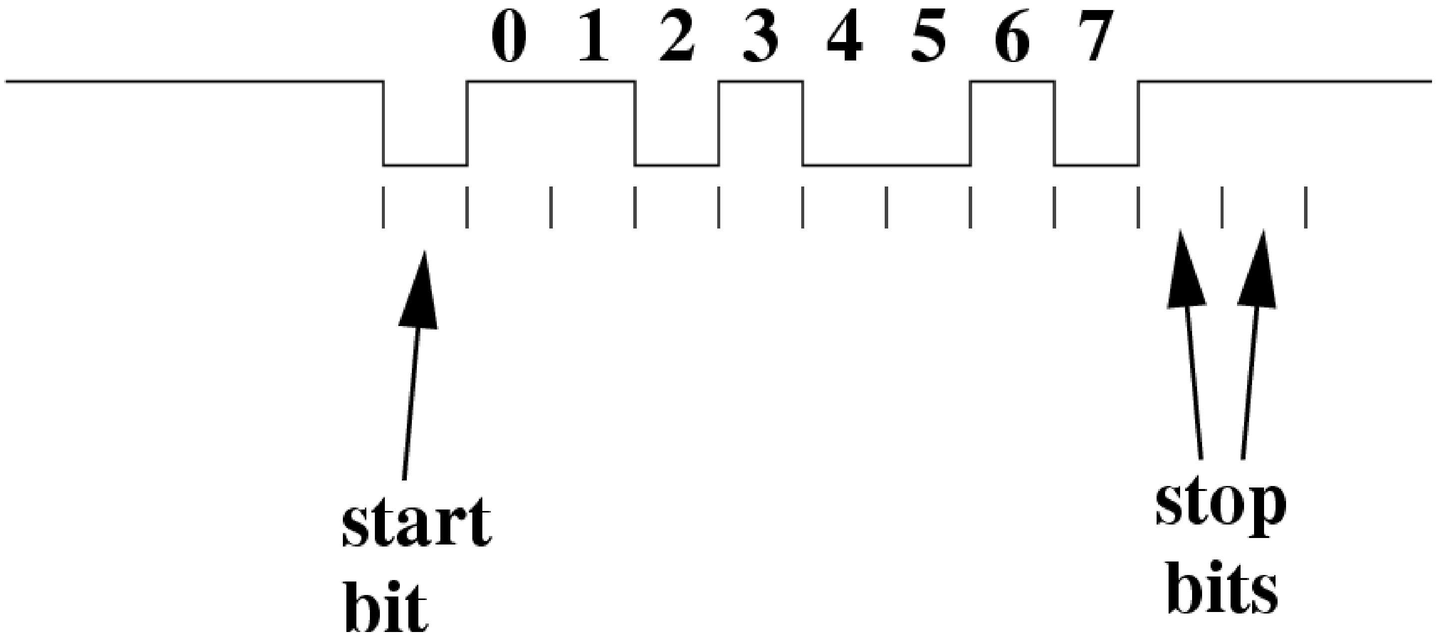
- Must both be operating at essentially the same transmit/receive frequency
- A data byte is prefaced with a bit of information that tells the receiver that bits are coming
- The receiver uses the arrival time of this **start bit** to synchronize its clock

A Typical Data Frame



The start bit indicates that a byte is coming

A Typical Data Frame



The stop bits allow the receiver to immediately check whether this is a valid frame

- If not, the byte is thrown away

Data Frame Handling

Most of the time, we do not deal with the data frame level. Instead, we rely on:

- Hardware solutions: Universal Asynchronous Receiver Transmitter (UART)
  - Very common in computing devices
- Software solutions in libraries

One (Old) Standard: RS232-C

Defines a logic encoding standard:

- “High” is encoded with a voltage of -5 to -15 (-12 to -13V is typical)
- “Low” is encoded with a voltage of 5 to 15 (12 to 13V is typical)

RS232 on the Mega2560

Our mega 2560 has FOUR Universal, Asynchronous serial Receiver/Transmitters (UARTs):

- Each handles all of the bit-level manipulation
  - Software only worries about the byte level
- Uses 0V and 5V to encode “lows” and “highs”
  - Must convert if talking to a true RS232C device (+/- 13V)

Mega2560 UART C Interface

Lib C support (standard C):

`char fgetc(fp)` : receive a character

`fputc('a', fp)` : put a character out to the port

`fputs("foobar", fp)` : put a string out to the port

`fprintf(fp, "foobar %d %s", 45, "baz")`:
put a formatted string out to the port

Mega2560 UART C Interface

OUlib support:

```
fp = serial_init_buffered(1, 38400, 40, 40)
```

Initialize port one for a transmission rate of 38400 bits per second (input and output buffers are both 40 characters long)

Note: declare fp as a global variable:

```
FILE *fp;
```

```
serial_buffered_input_waiting(fp)
```

Is there a character in the buffer?

See the Atmel HOWTO: examples_2560/serial

Reading a Byte from the Serial Port

```
int c;

c=fgetc(fp);
```

Note: fgetc() “blocks” until a byte is available

- Will only return with a value once a character is available to be returned

Processing Serial Input

```
int c;
while(1) {
  if(serial_buffered_input_waiting(fp)) {
     // A character is available for reading
     c = fgetc(fp);
     <do something with the character>
  }
  <do something else while waiting>
}
```

serial_buffered_input_waiting(fp) tells us whether a byte is ready to be read

Mega2560 UART C Interface

Also available:

- `fscanf()`: formatted input

See the LibC documentation or the AVR C textbook

Character Representation

- A “char” is just an 8-bit number
- This allows us to perform meaningful mathematical operations on the characters

Character Representation: ASCII

Binary	Dec	Hex	Glyph
010 0000	32	20	SP
010 0001	33	21	!
010 0010	34	22	"
010 0011	35	23	#
010 0100	36	24	$
010 0101	37	25	%
010 0110	38	26	&
010 0111	39	27	'
010 1000	40	28	(
010 1001	41	29	)
010 1010	42	2A	*
010 1011	43	2B	+
010 1100	44	2C	,
010 1101	45	2D	-
010 1110	46	2E	.
010 1111	47	2F	/
011 0000	48	30	0
011 0001	49	31	1
011 0010	50	32	2
011 0011	51	33	3
011 0100	52	34	4
011 0101	53	35	5
011 0110	54	36	6
011 0111	55	37	7
011 1000	56	38	8
011 1001	57	39	9
011 1010	58	3A	:
011 1011	59	3B	;
011 1100	60	3C	<
011 1101	61	3D	=
011 1110	62	3E	>
011 1111	63	3F	?

Binary	Dec	Hex	Glyph
100 0000	64	40	@
100 0001	65	41	A
100 0010	66	42	B
100 0011	67	43	C
100 0100	68	44	D
100 0101	69	45	E
100 0110	70	46	F
100 0111	71	47	G
100 1000	72	48	H
100 1001	73	49	I
100 1010	74	4A	J
100 1011	75	4B	K
100 1100	76	4C	L
100 1101	77	4D	M
100 1110	78	4E	N
100 1111	79	4F	O
101 0000	80	50	P
101 0001	81	51	Q
101 0010	82	52	R
101 0011	83	53	S
101 0100	84	54	T
101 0101	85	55	U
101 0110	86	56	V
101 0111	87	57	W
101 1000	88	58	X
101 1001	89	59	Y
101 1010	90	5A	Z
101 1011	91	5B	[
101 1100	92	5C	\
101 1101	93	5D	]
101 1110	94	5E	^
101 1111	95	5F	_

Binary	Dec	Hex	Glyph
110 0000	96	60	`
110 0001	97	61	a
110 0010	98	62	b
110 0011	99	63	c
110 0100	100	64	d
110 0101	101	65	e
110 0110	102	66	f
110 0111	103	67	g
110 1000	104	68	h
110 1001	105	69	i
110 1010	106	6A	j
110 1011	107	6B	k
110 1100	108	6C	l
110 1101	109	6D	m
110 1110	110	6E	n
110 1111	111	6F	o
111 0000	112	70	p
111 0001	113	71	q
111 0010	114	72	r
111 0011	115	73	s
111 0100	116	74	t
111 0101	117	75	u
111 0110	118	76	v
111 0111	119	77	w
111 1000	120	78	x
111 1001	121	79	y
111 1010	122	7A	z
111 1011	123	7B	{
111 1100	124	7C	|
111 1101	125	7D	}
111 1110	126	7E	~

Buffers

A buffer is an array that temporarily stores data in sequential order

```
fp = serial_init_buffered(1, 38400, 40, 40)
```

- Declares both the input and output buffer sizes to be 40 bytes

Output Buffer

- Any characters that are produced (e.g., with fputc() or fprintf()) are first placed in the output buffer
- Then, the serial hardware removes one byte at a time to send it

Output Buffer

- Advantage: fputc() and fprintf() don't have to wait for the bytes to be transmitted
  - Your program can keep doing the rest of its job
- But: if the buffer fills up, these functions will block until there is space
  - You must choose your buffer size somewhat carefully

Input Buffer

Temporary storage of bytes as they are received

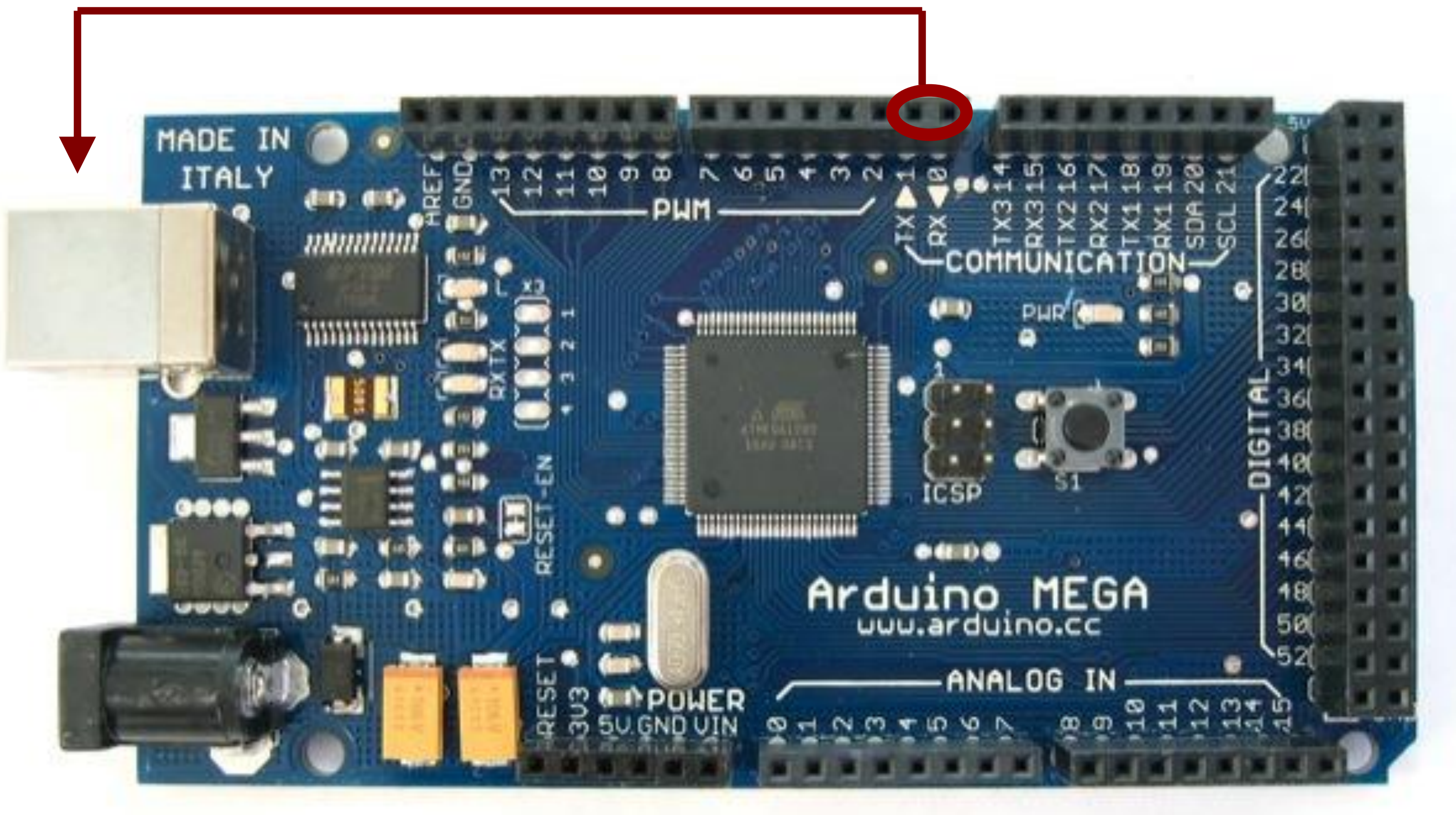
- Your program can read these bytes at its leisure
- With OULIB: if the buffer fills up, then additional bytes will be lost

Physical Interface

Four matched pairs of transmit and receive pins (TX? and RX?)

Physical Interface

Port 0 is also connected to the USB port



See “realterm” on downloads page

Serial Challenge

- Suppose that we know that we will be receiving a sequence of 3 decimal digits from the serial port
- How do we translate these digits into an integer representation?
- Bonus: what if we don't know how many digits are coming? (we read digits until a non-digit is read)

Character Representation: ASCII

Binary	Dec	Hex	Glyph
010 0000	32	20	SP
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101 1001	89	59	Y
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101 1101	93	5D	]
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110 0100	100	64	d
110 0101	101	65	e
110 0110	102	66	f
110 0111	103	67	g
110 1000	104	68	h
110 1001	105	69	i
110 1010	106	6A	j
110 1011	107	6B	k
110 1100	108	6C	l
110 1101	109	6D	m
110 1110	110	6E	n
110 1111	111	6F	o
111 0000	112	70	p
111 0001	113	71	q
111 0010	114	72	r
111 0011	115	73	s
111 0100	116	74	t
111 0101	117	75	u
111 0110	118	76	v
111 0111	119	77	w
111 1000	120	78	x
111 1001	121	79	y
111 1010	122	7A	z
111 1011	123	7B	{
111 1100	124	7C	|
111 1101	125	7D	}
111 1110	126	7E	~

Next Time

- Project 6