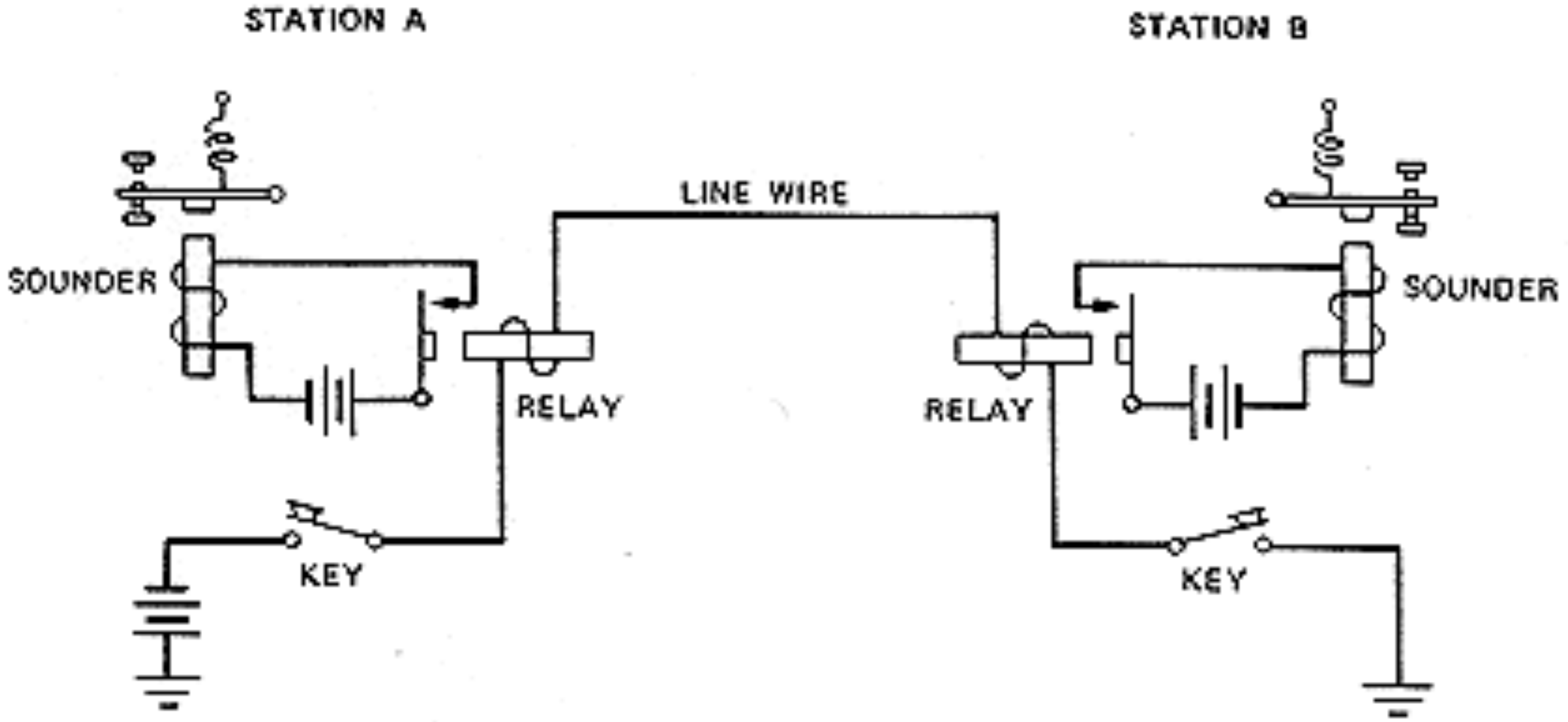
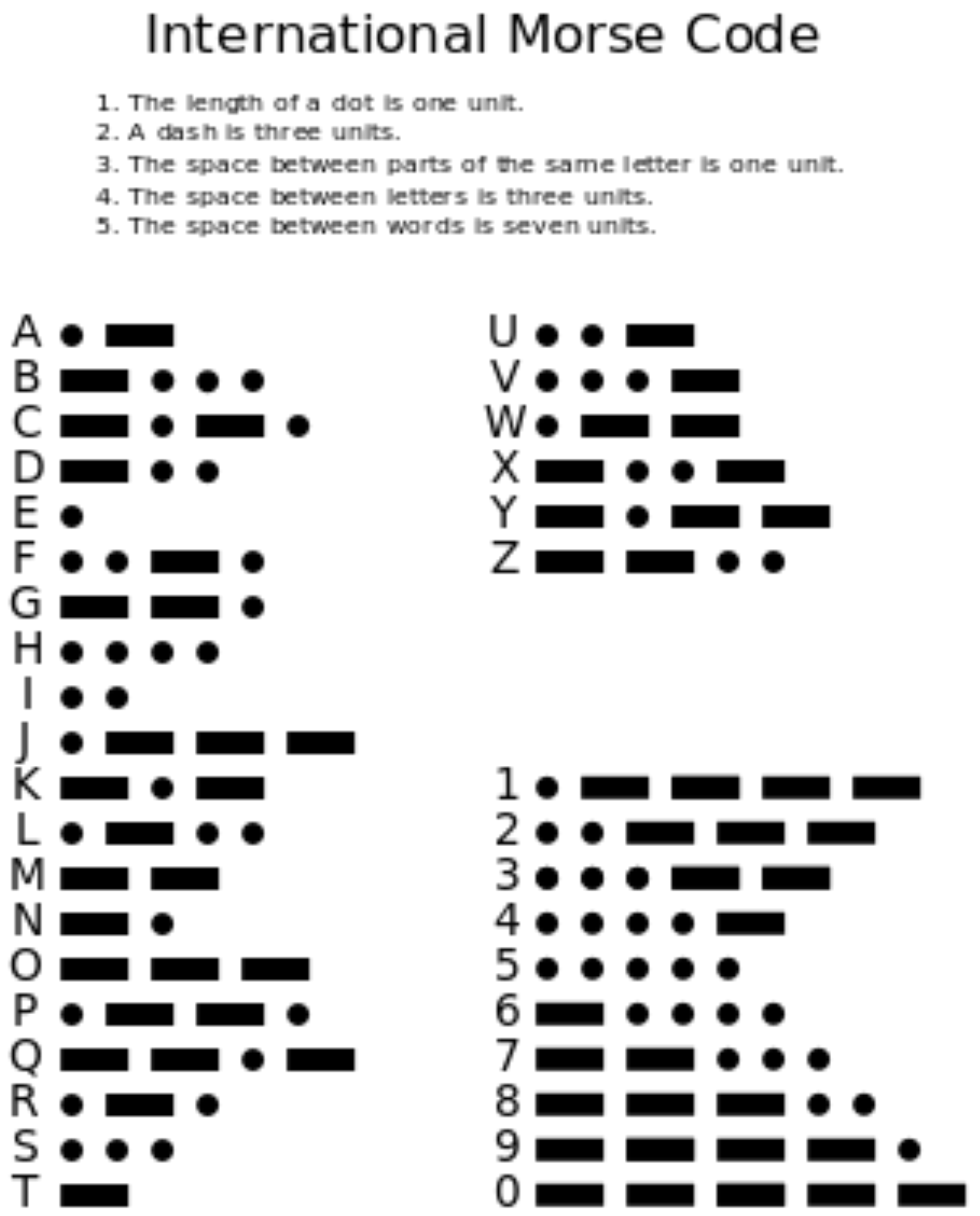
The Serial Protocol
and
ASCII Character Codes

Simplex Telegraph



Elementary neutral telegraph circuit.

http://people.seas.harvard.edu/~jones/cscie129/nu_lectures/lecture5/elecmag_tel/morse_tel.html



International Morse Code

1. The length of a dot is one unit.
2. A dash is three units.
3. The space between parts of the same letter is one unit.
4. The space between letters is three units.
5. The space between words is seven units.

A	● ▬
B	▬ ● ● ●
C	▬ ● ▬ ●
D	▬ ● ●
E	●
F	● ● ▬ ●
G	▬ ▬ ●
H	● ● ● ●
I	● ●
J	● ▬ ▬ ▬
K	▬ ● ▬
L	● ▬ ● ●
M	▬ ▬
N	▬ ●
O	▬ ▬ ▬
P	● ▬ ▬ ●
Q	▬ ▬ ● ▬
R	● ▬ ●
S	● ● ●
T	▬
U	● ● ▬
V	● ● ● ▬
W	● ▬ ▬
X	▬ ● ● ▬
Y	▬ ● ▬ ▬
Z	▬ ▬ ● ●
1	● ▬ ▬ ▬ ▬
2	● ● ▬ ▬ ▬
3	● ● ● ▬ ▬
4	● ● ● ● ▬
5	● ● ● ● ●
6	▬ ● ● ● ●
7	▬ ▬ ● ● ●
8	▬ ▬ ▬ ● ●
9	▬ ▬ ▬ ▬ ●
0	▬ ▬ ▬ ▬ ▬

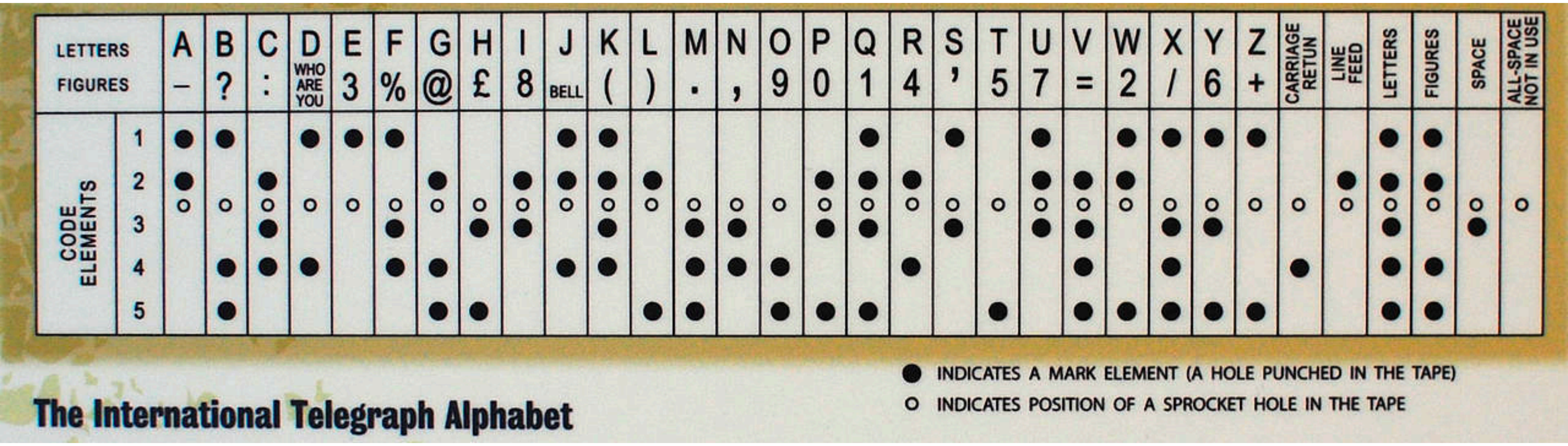
https://en.wikipedia.org/wiki/Morse_code

blink.c -> sos.c

Teletype

http://www.smecc.org/police_-__fire_-_civil_defense_communications.htm

5-bit Baudot Code (1870)



LETTERS		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	CARRIAGE RETUN	LINE FEED	LETTERS	FIGURES	SPACE	ALL-SPACE NOT IN USE
FIGURES		–	?	:	WHO ARE YOU	3	%	@	£	8	BELL	(	)	.	,	9	0	1	4	’	5	7	=	2	/	6	+						
CODE ELEMENTS	1	●	●		●	●	●				●	●						●		●		●		●	●	●	●			●	●		
	2	●		●				●		●	●	●	●				●	●	●			●	●	●					●	●	●		
		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	3			●			●		●	●		●		●	●		●	●		●		●	●		●	●				●		●	
	4		●	●	●		●	●			●	●		●	●	●			●				●		●			●		●	●		
	5		●					●	●				●	●		●	●	●			●		●	●	●	●	●			●	●		

● INDICATES A MARK ELEMENT (A HOLE PUNCHED IN THE TAPE)

○ INDICATES POSITION OF A SPROCKET HOLE IN THE TAPE

The International Telegraph Alphabet

Baud: Number of symbols per second

https://en.wikipedia.org/wiki/Baudot_code

7-bit ASCII

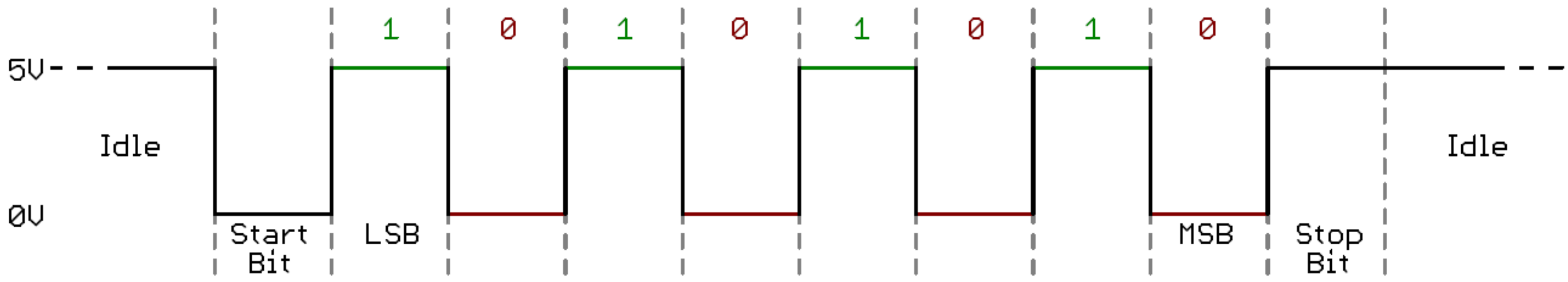
```
% ascii
   2 3 4 5 6 7
 -------------
0:   0 @ P ' p
1: ! 1 A Q a q
2: " 2 B R b r
3: # 3 C S c s
4: $ 4 D T d t
5: % 5 E U e u
6: & 6 F V f v
7: ' 7 G W g w
8: ( 8 H X h x
9: ) 9 I Y i y
A: * : J Z j z
B: + ; K [ k {
C: , < L \ l |
D: - = M ] m }
E: . > N ^ n ~
F: / ? O _ o DEL
```

"cs107e" =

\0
64
37
30
31
73
63

0x68 stands for 'h'

Asynchronous Serial Communication



1 start bit (0), 8 data bits (lsb-first), 1 stop bit (1)

9600 baud = 9600 bits/sec

(1000000 usecs)/9600 ~ 104 usec/bit

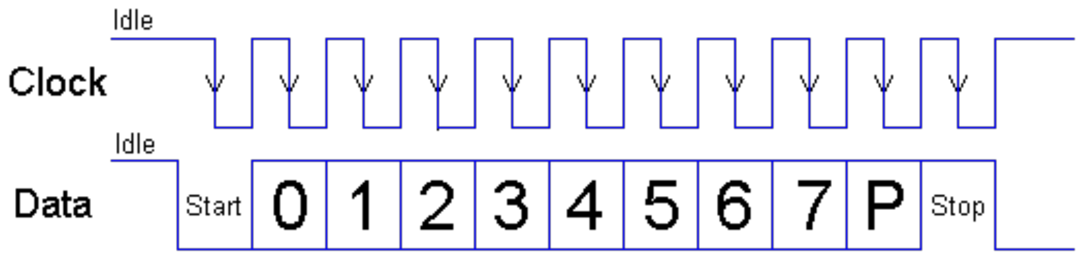
https://learn.sparkfun.com/tutorials/serial-communication

Synchronous Protocol: PS/2

Synchronous protocol: clock and data

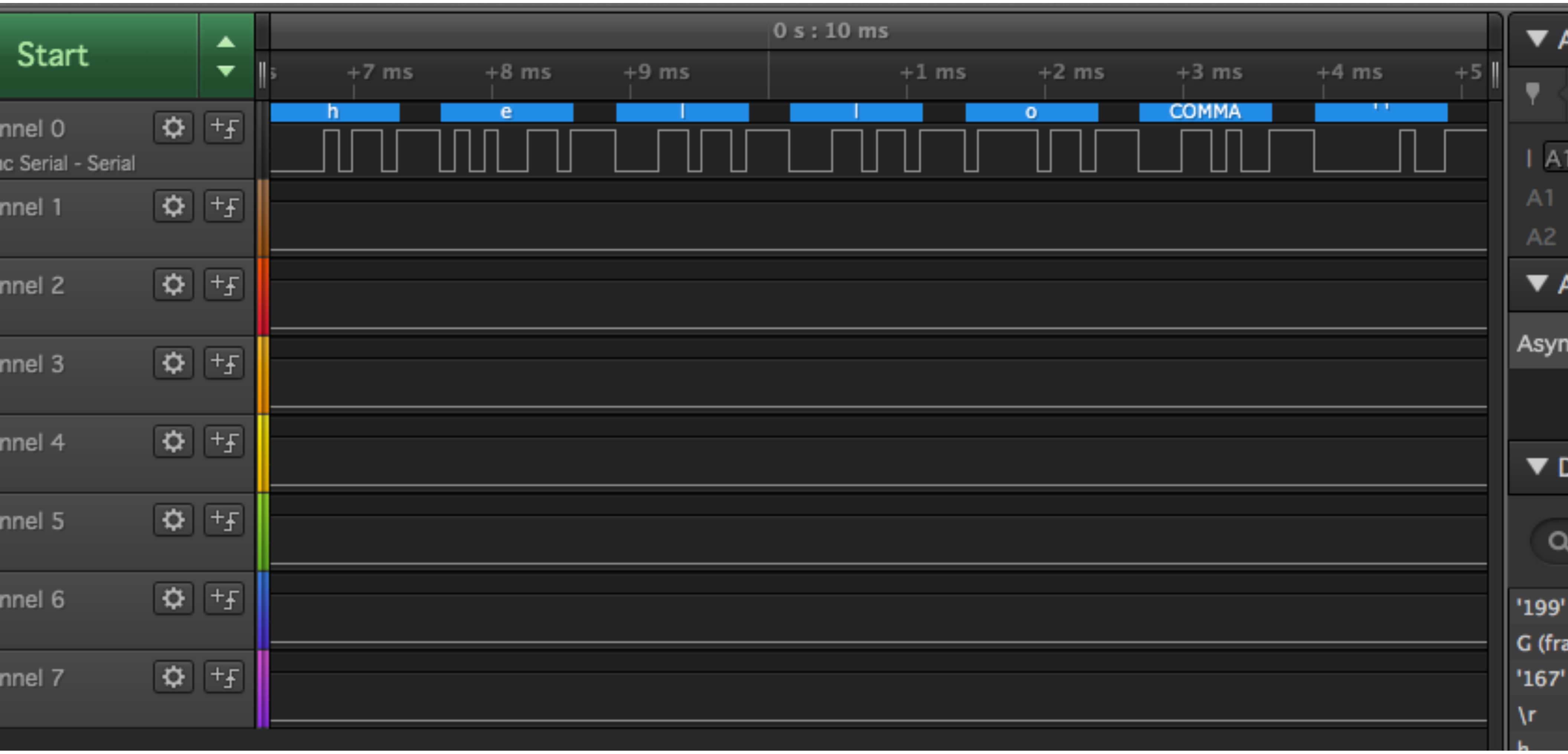
- Data changes when clock line is high
- Host reads data when clock is low

Payload: start bit, 8 data bits (lsb-first), 1 parity bit, 1 stop bit (11 total)

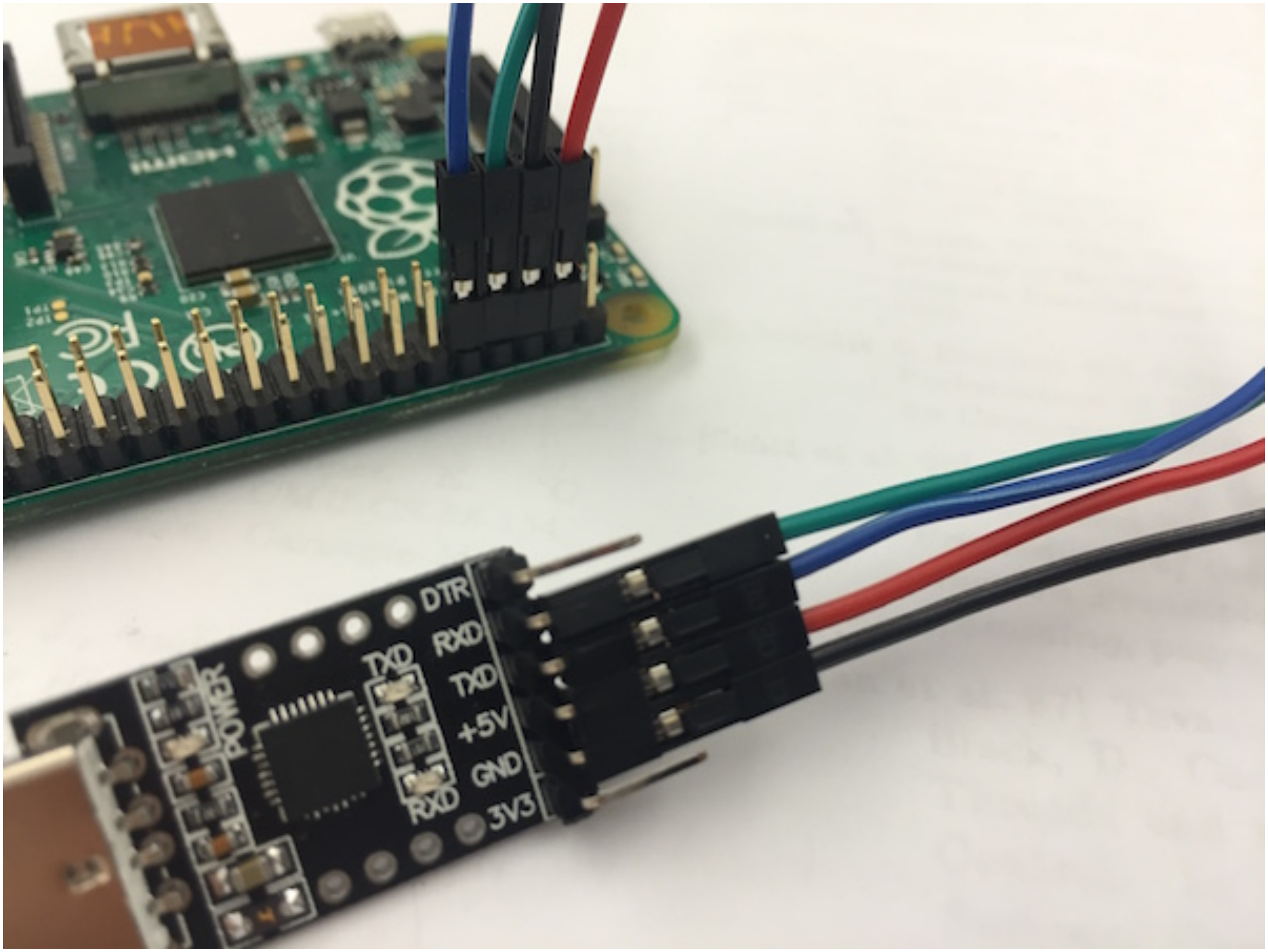


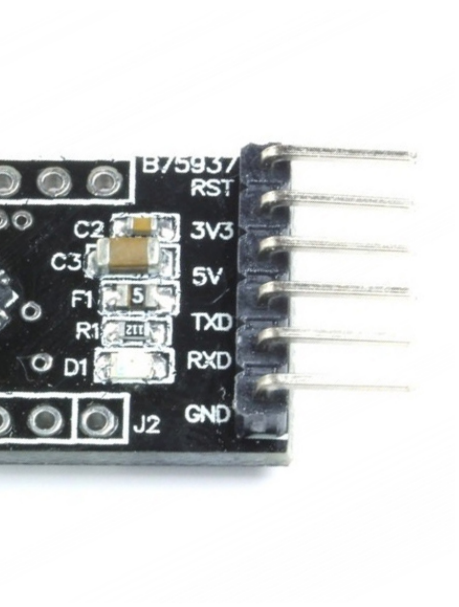
```
sos.c -> serial.c
```

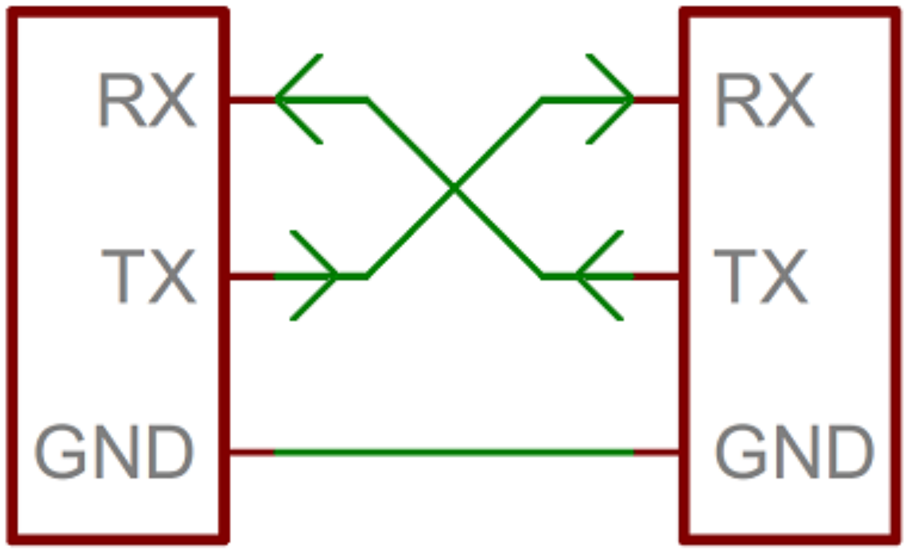
Logic Analyzer!

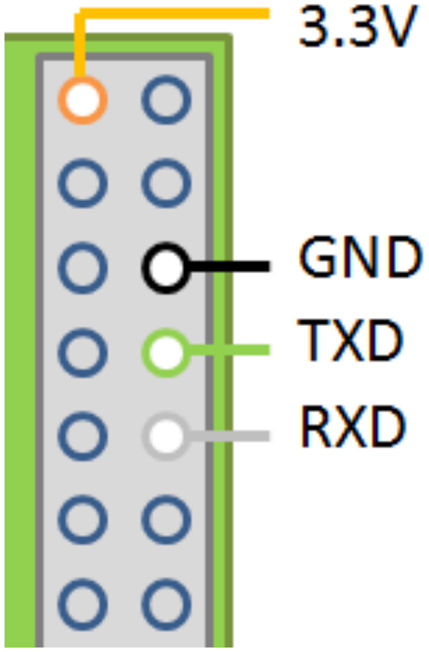


```
// hot wire TX

// device = tty (teletype)
// baud rate = 9600

% screen /dev/tty.SLAB_USBtoUART 9600

CTRL-A K - to exit
```


DTR
RXD
TXD
+5V
GND
3V3
TXD
RXD
POWER



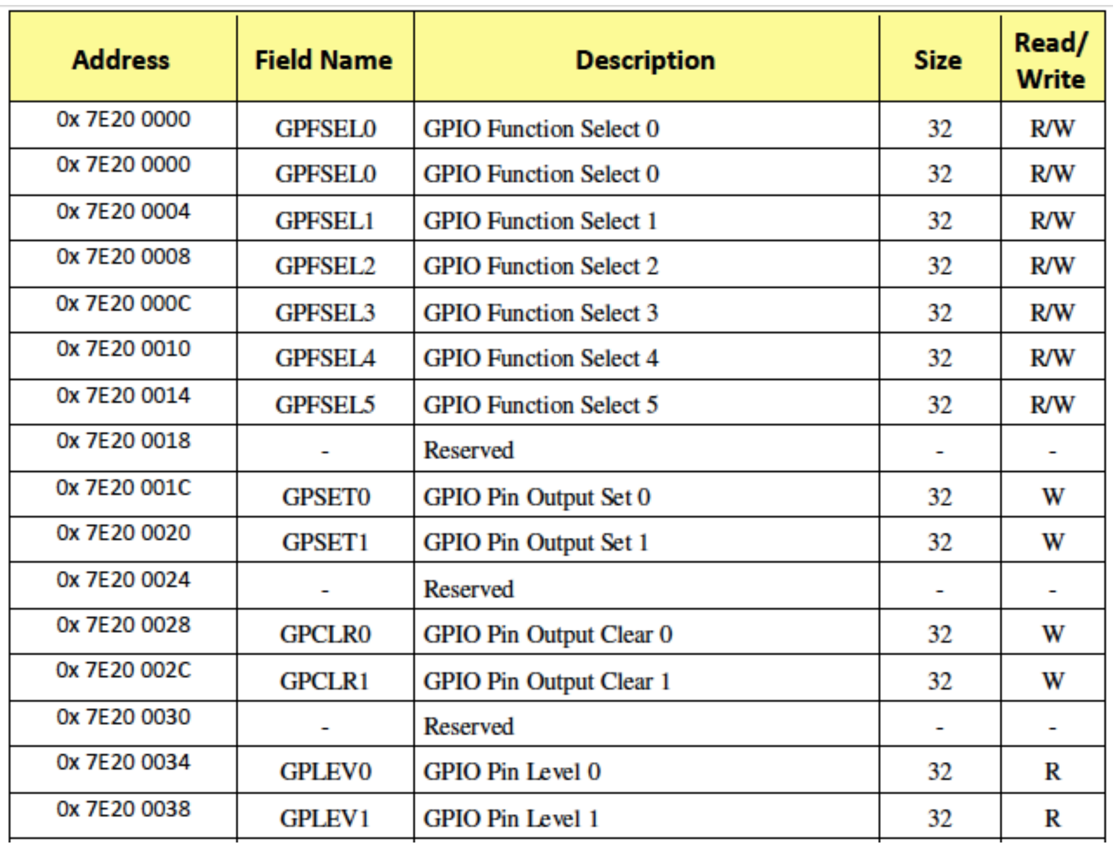




```
% screen /dev/tty.SLAB_USBtoUART 115200
```

Power of Types and Pointers

```
struct gpio {
  unsigned int fsel[6];
  unsigned int reservedA;
  unsigned int set[2];
  unsigned int reservedB;
  unsigned int clr[2];
  unsigned int reservedC;
  unsigned int lev[2];
};
```



Address	Field Name	Description	Size	Read/ Write
0x 7E20 0000	GPFSEL0	GPIO Function Select 0	32	R/W
0x 7E20 0000	GPFSEL0	GPIO Function Select 0	32	R/W
0x 7E20 0004	GPFSEL1	GPIO Function Select 1	32	R/W
0x 7E20 0008	GPFSEL2	GPIO Function Select 2	32	R/W
0x 7E20 000C	GPFSEL3	GPIO Function Select 3	32	R/W
0x 7E20 0010	GPFSEL4	GPIO Function Select 4	32	R/W
0x 7E20 0014	GPFSEL5	GPIO Function Select 5	32	R/W
0x 7E20 0018	-	Reserved	-	-
0x 7E20 001C	GPSET0	GPIO Pin Output Set 0	32	W
0x 7E20 0020	GPSET1	GPIO Pin Output Set 1	32	W
0x 7E20 0024	-	Reserved	-	-
0x 7E20 0028	GPCLR0	GPIO Pin Output Clear 0	32	W
0x 7E20 002C	GPCLR1	GPIO Pin Output Clear 1	32	W
0x 7E20 0030	-	Reserved	-	-
0x 7E20 0034	GPLEV0	GPIO Pin Level 0	32	R
0x 7E20 0038	GPLEV1	GPIO Pin Level 1	32	R

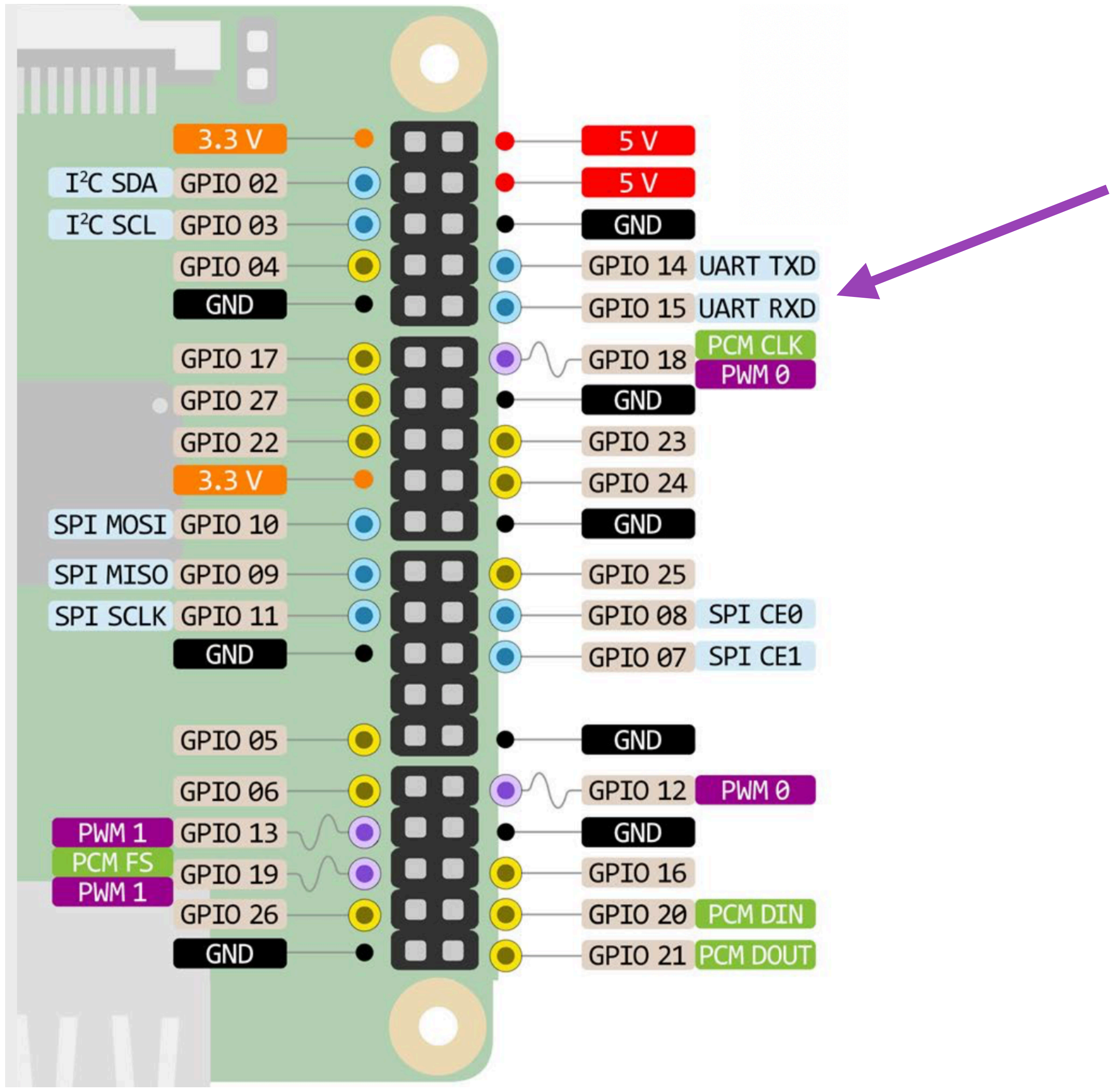
```
volatile struct gpio *gpio = (struct gpio *)0x20200000;
gpio->fsel[0] = ...
```

`uart.h, uart.c`

Universal Asynchronous Receiver-Transmitter

```
// BCM2835-ARM-Peripherals.pdf
// Sec 2: Mini-UART, SPI0, SPI1, pp 8-19
struct UART {
    unsigned data; // I/O Data
    unsigned ier;  // Interrupt enable
    unsigned iir;  // Interrupt identify/fifo
    unsigned lcr;  // line control register
    unsigned mcr;  // modem control register
    unsigned lsr;  // line status
    unsigned msr;  // modem status
    unsigned scratch;
    unsigned cntl; // control register
    unsigned stat; // status register
    unsigned baud; // baud rate register
} ;
```

GPIO Alternate Functions



GPIO ALT Function

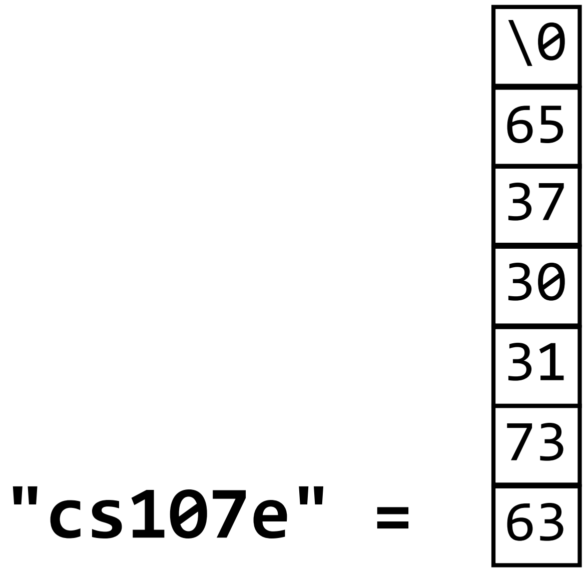
Every GPIO pin can be input, output, or one of 6 special functions (ALT0-ALT5), specific to each pin.

PIN	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
GPIO14	TXD0	SD6				TXD1
GPIO15	RXD0	SD7				RXD1

echo.c

loop back test

C Strings



```
// Note '\0' at the end!
char arr[] =
    ['c','s','1','0','7','e','\0'];
// short cut
char arr[] = "cs107e";

char ch = arr[1]; // ok? ch?

char *ptr = "cs107e";
ch = ptr[1];

arr = ptr; // ok?
ptr = arr; // ok?
```

String Functions in string.h

`strcat(s1,s2)`	Concatenate s2 to s1
`strncat(s1,s2,n)`	Concatenate at most n characters of s2 to s1
`strcpy(s1,s2)`	Copy s2 to s1; Note the direction of the copy!
`strncpy(s1,s2,n)`	Copy first n characters of s2 to s1
`strlen(s)`	Return length of string s, not counting ‘\0'
`strcmp(s1,s2)`	Compare s1 with s2; Return integer less than zero, equal to zero, or greater than zero
`strncmp(s1,s2,n)`	Compare only the first n characters of s1 and s2
`strchr(s,c)`	Return a pointer to first occurrence of character c in string s; return NULL if not found
`strrchr(s,c)`	Return a pointer to last occurrence of character c in string s; return NULL if not found
`strstr(s1,s2)`	Return a pointer to the first occurrence of string s1 in string s2; return NULL if not found
`strstr(s1,s2)`	Return a pointer to the first occurrence of string s1 in string s2; return zero if not found

```
size_t strlen(const char *str)
{
  for (const char *s = str; *s; ++s)
      ;
  return (s - str);
}

// strlen("a")?
// strlen(NULL)?
// strlen('a')?
// Assignment 3

/*
** printf(const char *format, …);
*/

printf("%d, %d\n", 1, 2);
printf(“%x\n", 0x20200008);
printf("%c\n", 'a');
printf("%s\n", "hello");

// Lots of practice with pointers!
```