Types

Last updated 6/15/23

These slides introduce ‘types’ of entities used in C

Types

Quick Aside:

- A variable is a name for some entity stored in memory
- We refer to the entity by name (the variable) because we don't know the value
- Just like in algebra

Types

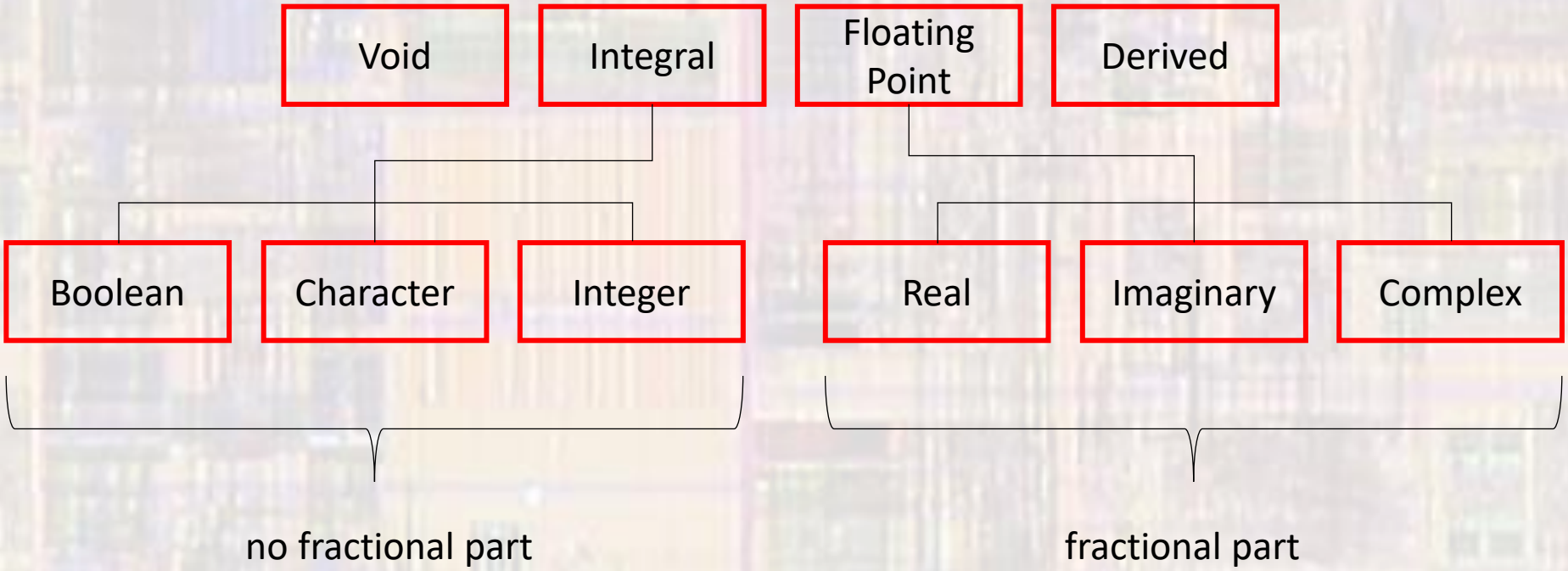
- What is a Type
  - The “space” in which a variable is defined
  - Space
    - All possible allowed values
    - All defined operations
  - Integer Space
    - whole numbers
    - +, -, x
    - No divide

Types

- Why Types
  - No room for confusion in a computer
    - Must get the same answer every time
  - Everything must be stored into memory somewhere
    - Program Memory
    - Data Memory
  - Memory used to be expensive
    - Minimize the amount needed

Types

- C Types



Types

- void
  - No values
  - No defined operations
  - Used when we want to indicate that nothing is here
  - Examples

```
MyFunction(void);
// call a function with no input parameters

void YourFunction(int val){    …
// indicate that a function returns nothing
```

Types

- bool - boolean
  - 2 values
    - true, false
  - Logical operations
    - and (&&) or (||) not (!)
  - All numbers except 0 (0.0) are True
  - 0, 0.0 are False

** We have not covered logical operations yet

Types

- char - character
  - ASCII - 128 values
    - a,b,c,1,2,3,$,%,*, …
    - English language characters
  - Unicode – millions of values
  - Stored in the computer as integers
    - Same operations as integers
  - Become characters when visualized
  - Rules:
    - A character is a SINGLE character
    - Require a single quote

Types

NULL – no character

numbers add 0x30

ASCII TABLE

Decimal	Hexadecimal	Binary	Octal	Char
0	0	0	0	[NULL]
1	1	1	1	[START OF HEADING]
2	2	10	2	[START OF TEXT]
3	3	11	3	[END OF TEXT]
4	4	100	4	[END OF TRANSMISSION]
5	5	101	5	[ENQUIRY]
6	6	110	6	[ACKNOWLEDGE]
7	7	111	7	[BELL]
8	8	1000	10	[BACKSPACE]
9	9	1001	11	[HORIZONTAL TAB]
10	A	1010	12	[LINE FEED]
11	B	1011	13	[VERTICAL TAB]
12	C	1100	14	[FORM FEED]
13	D	1101	15	[CARRIAGE RETURN]
14	E	1110	16	[SHIFT OUT]
15	F	1111	17	[SHIFT IN]
16	10	10000	20	[DATA LINK ESCAPE]
17	11	10001	21	[DEVICE CONTROL 1]
18	12	10010	22	[DEVICE CONTROL 2]
19	13	10011	23	[DEVICE CONTROL 3]
20	14	10100	24	[DEVICE CONTROL 4]
21	15	10101	25	[NEGATIVE ACKNOWLEDGE]
22	16	10110	26	[SYNCHRONOUS IDLE]
23	17	10111	27	[ENG OF TRANS. BLOCK]
24	18	11000	30	[CANCEL]
25	19	11001	31	[END OF MEDIUM]
26	1A	11010	32	[SUBSTITUTE]
27	1B	11011	33	[ESCAPE]
28	1C	11100	34	[FILE SEPARATOR]
29	1D	11101	35	[GROUP SEPARATOR]
30	1E	11110	36	[RECORD SEPARATOR]
31	1F	11111	37	[UNIT SEPARATOR]
32	20	100000	40	[SPACE]
33	21	100001	41	!
34	22	100010	42	"
35	23	100011	43	#
36	24	100100	44	$
37	25	100101	45	%
38	26	100110	46	&
39	27	100111	47	'
40	28	101000	50	(
41	29	101001	51	)
42	2A	101010	52	*
43	2B	101011	53	+
44	2C	101100	54	,
45	2D	101101	55	-
46	2E	101110	56	.
47	2F	101111	57	/
48	30	110000	60	0
49	31	110001	61	1
50	32	110010	62	2
51	33	110011	63	3
52	34	110100	64	4
53	35	110101	65	5
54	36	110110	66	6
55	37	110111	67	7
56	38	111000	70	8
57	39	111001	71	9
58	3A	111010	72	:
59	3B	111011	73	;
60	3C	111100	74	<
61	3D	111101	75	=
62	3E	111110	76	>
63	3F	111111	77	?
64	40	1000000	100	@
65	41	1000001	101	A
66	42	1000010	102	B
67	43	1000011	103	C
68	44	1000100	104	D
69	45	1000101	105	E
70	46	1000110	106	F
71	47	1000111	107	G
72	48	1001000	110	H
73	49	1001001	111	I
74	4A	1001010	112	J
75	4B	1001011	113	K
76	4C	1001100	114	L
77	4D	1001101	115	M
78	4E	1001110	116	N
79	4F	1001111	117	O
80	50	1010000	120	P
81	51	1010001	121	Q
82	52	1010010	122	R
83	53	1010011	123	S
84	54	1010100	124	T
85	55	1010101	125	U
86	56	1010110	126	V
87	57	1010111	127	W
88	58	1011000	130	X
89	59	1011001	131	Y
90	5A	1011010	132	Z
91	5B	1011011	133	[
92	5C	1011100	134	\
93	5D	1011101	135	]
94	5E	1011110	136	^
95	5F	1011111	137	_
96	60	1100000	140	`
97	61	1100001	141	a
98	62	1100010	142	b
99	63	1100011	143	c
100	64	1100100	144	d
101	65	1100101	145	e
102	66	1100110	146	f
103	67	1100111	147	g
104	68	1101000	150	h
105	69	1101001	151	i
106	6A	1101010	152	j
107	6B	1101011	153	k
108	6C	1101100	154	l
109	6D	1101101	155	m
110	6E	1101110	156	n
111	6F	1101111	157	o
112	70	1110000	160	p
113	71	1110001	161	q
114	72	1110010	162	r
115	73	1110011	163	s
116	74	1110100	164	t
117	75	1110101	165	u
118	76	1110110	166	v
119	77	1110111	167	w
120	78	1111000	170	x
121	79	1111001	171	y
122	7A	1111010	172	z
123	7B	1111011	173	{
124	7C	1111100	174	|
125	7D	1111101	175	}
126	7E	1111110	176	~
127	7F	1111111	177	[DEL]

upper and lower case differ by hex 0x20

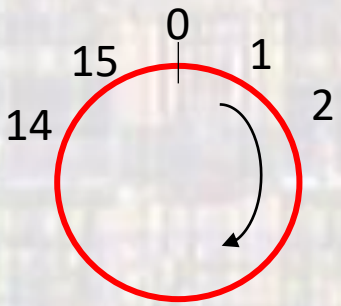
Types

- int - integer
  - Values are system dependent
    - integers only
    - 2, 4, 8 bytes
    - short int, int, long int, long long int
  - Operations
    - Arithmetic operations +, -, *, /, %
    - Comparison operations <, >, <=, >=, ==, !=
    - Bitwise operations ~, |, &, ^, <<, >>

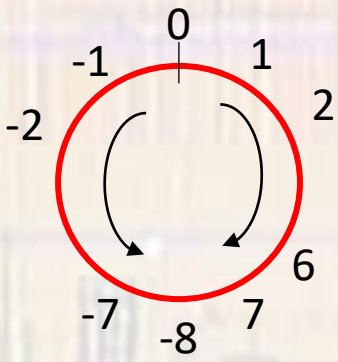
** We have not covered operations yet

Types

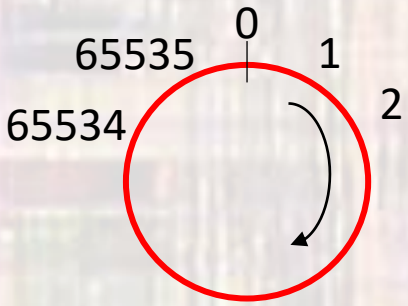
- int - integer
  - Special considerations with type int
    - Range is defined and limited
    - SIGNED and UNSIGNED variants
    - Overflow is ignored – values wrap around



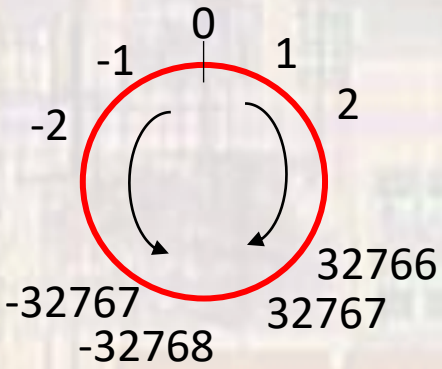
4 bit unsigned



4 bit signed



16 bit unsigned



16 bit signed

Types

- int - integer
  - Laptop

```
size of short int = 2  Bytes
example short int: 32767
example short int + 1: -32768

size of plain int = 4  Bytes
example plain int: 2147483647
example plain int + 1: -2147483648

size of long int = 4 Bytes
example long int: 2147483647
example long int + 1: -2147483648

size of long long int = 8  Bytes
example long long int: -1
example long long int + 1: 0
```

Types

- special integers
  - A special set of integers are defined for embedded systems
    - Designed to allow register/memory access
    - Not system dependent

```
#include <stdint.h>
signed char          int8_t;
unsigned char        uint8_t;
short                int16_t;
unsigned short       uint16_t;
int                  int32_t;
unsigned             uint32_t;
long long            int64_t;
unsigned long long   uint64_t;
```

Types

- float – real
  - Values are system dependent
    - SIGNED
    - 4 byte – 1,8,23
    - 8 byte – 1,11,52
    - float, double, long double
  - Operations
    - Arithmetic operations +, -, *, /
    - Comparison operations <, >, <=, >=, ==, !=

** We have not covered operations yet

Types

- float imaginary
  - Values are system dependent
    - SIGNED
    - 4 byte – 1,8,23
    - 8 byte – 1,11,52
    - float imaginary, double imaginary, long double imaginary
  - Operations
    - Arithmetic operations +, -, *, /
    - Comparison operations <, >, <=, >=, ==, !=
  - Not supported in some systems

** We have not covered operations yet

Types

- float complex
  - Values are system dependent
    - SIGNED
    - 4 byte – 1,8,23
    - 8 byte – 1,11,52
    - float complex, double complex, long double complex
  - Operations
    - Arithmetic operations +, -, *, /
    - Comparison operations <, >, <=, >=, ==, !=
  - Real and imaginary parts must be the same size

** We have not covered operations yet

Types

- Special Details
  - Functions:

    sizeof(type)

    sizeof expression

    typeof(expression)

  - Include

    <limits.h>

    <float.h>

    <stdint.h>

SHRT_MIN	Minimum value for an object of type short int
SHRT_MAX	Maximum value for an object of type short int
USHRT_MAX	Maximum value for an object of type unsigned short int
INT_MIN	Minimum value for an object of type int
INT_MAX	Maximum value for an object of type int

defines max and min values for standard types