C (Basic) Data Types

-different data representations need different types in programming-

C BASIC (DATA) TYPES

In C, data type categorized as:

1. Primitive Types in ANSI C (C89)/ISO C (C90) - `char`, `short`, `int`, `float` and `double`.
2. Primitive Types added to ISO C (C99) - `long long`
3. User Defined Types – `struct`, `union`, `enum` and `typedef` (will be discussed in separate session).
4. Derived Types – pointer, array and function pointer (will be discussed in separate session).

C BASIC (DATA) TYPES

Type	Size in Bits	Comments	Other Names
Primitive Types in ANSI C (C89)/ISO C (C90)			
char	≥ 8	▪ **sizeof()** will give the size in units of **chars**. ▪ need not be 8-bit ▪ The number of bits is given by the CHAR_BIT macro in the limits.h header. ▪ Integer operations can be performed portably only for the range: 0 ~ 127 (2^8 / 2).	—
signed char	Same as **char** but guaranteed to be signed	▪ Can store integers in the range: -127 ~ 127 (2^8) portably.	—
unsigned char	Same as **char** but guaranteed to be unsigned.	▪ Can store integers in the range: 0 ~ 255 (2^8) portably.	—

char type program example

C BASIC (DATA) TYPES

- A sample output.

C:\WINDOWS\system32\cmd.exe

```
char value is A (65), its size is 1 byte.
signed char value is B (66), its size is 1 byte.
unsigned char value is C (67), its size is 1 byte.
Press any key to continue . . .
```

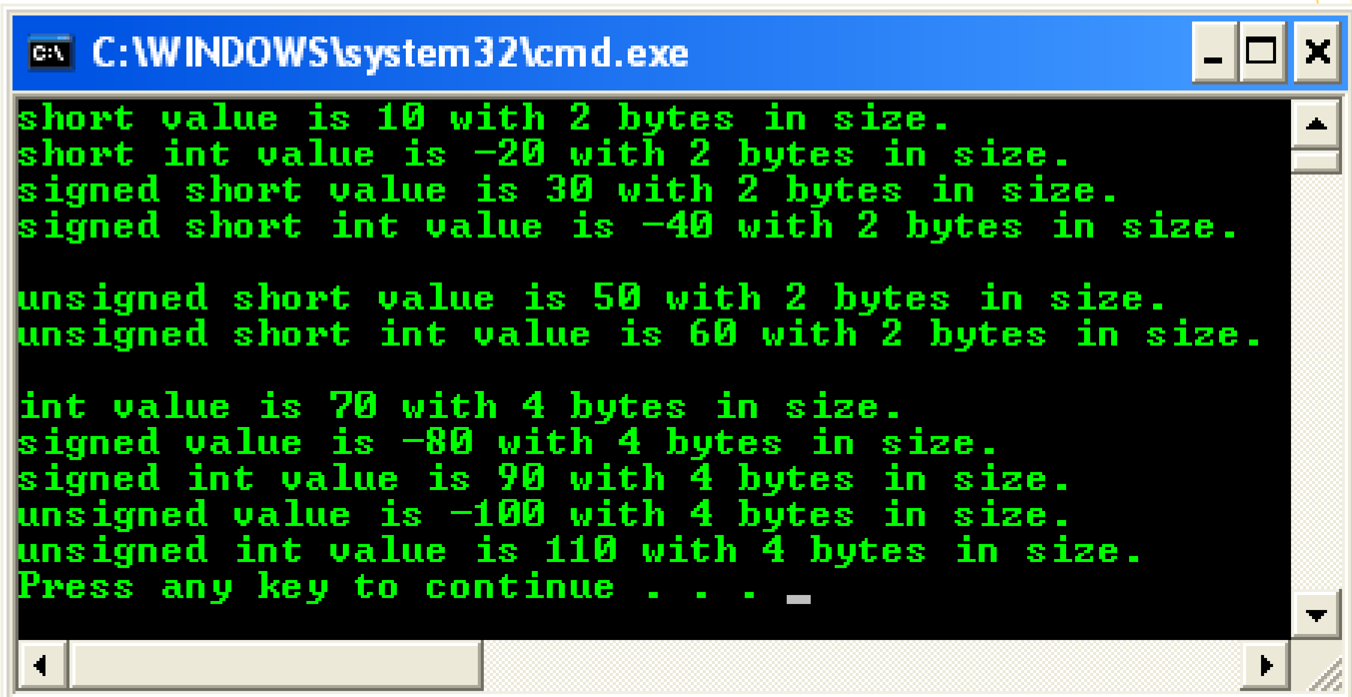
C BASIC (DATA) TYPES

short	≥ 16, ≥ size of **char**	▪ Can store integers in the range: -32767 ~ 32767 (2^{16} / 2) portably. ▪ Reduce memory usage though the resulting executable may be larger and probably slower as compared to using **int**.	**short int**, **signed short**, **signed short int**
unsigned short	Same as **short** but unsigned	▪ Can store integers in the range: 0 ~ 65535 (2^{16}) portably. ▪ Used to reduce memory usage though the resulting executable may be larger and probably slower as compared to using **int**.	**unsigned short int**
int	≥ 16, ≥ size of **short**	▪ Basic signed integer type. ▪ Represent a typical processor's data size which is word-size ▪ An integral data-type. ▪ Can store integers in the range: -32767 ~ 32767 (2^{16} / 2) portably.	**signed**, **signed int**
unsigned int	Same as **int** but unsigned.	▪ Can store integers in the range: 0 ~ 65535 (2^{16}) portably.	**unsigned**

short int type program example

C BASIC (DATA) TYPES

- A sample output.



C BASIC (DATA) TYPES

long	≥ 32, ≥ size of **int**	▪ long signed integer type. ▪ Can store integers in the range: -2147483647 ~ 2147483647 (2^{32} / 2) portably.	**long int**, **signed long**, **signed long int**
unsigned long	Same as **long** but unsigned	▪ Can store integers in the range: 0 ~ 4294967295 (2^{32}) portably.	**unsigned long int**
float	≥ size of **char**	▪ Used to reduce memory usage when the values used do not vary widely. ▪ The format used is implementation defined and unnecessarily obeys the IEEE 754 single-precision format. ▪ **unsigned** cannot be specified.	—
double	≥ size of **float**	▪ Typical floating-point data type used by processor. ▪ The format used is implementation defined and unnecessarily obeys the IEEE 754 double-precision format. ▪ **unsigned** cannot be specified.	—
long double	≥ size of **double**	▪ **unsigned** cannot be specified.	—

long int type program example

C BASIC (DATA) TYPES

- A sample output.

C:\WINDOWS\system32\cmd.exe

```
long value is -10000 with 4 bytes in size.
long int value is 200000 with 4 bytes in size.
signed long value is -3000000 with 4 bytes in size.
signed long int value is 40000000 with 4 bytes in size.
unsigned long value is 500000000 with 4 bytes in size.

float value is 6.712340 with 4 bytes in size.
double value is 789.652341 with 8 bytes in size.
long double value is 9796.617400 with 8 bytes in size.
Press any key to continue . . .
```

C BASIC (DATA) TYPES

Type	Size in Bits	Comments	Other Names
Primitive Types added to ISO C (C99)			
`long long`	≥ 64, ≥ size of **`long`**	▪ Can store integers in the range: -9223372036854775807 ~ 9223372036854775807 (2^{64} / 2) portably.	**long long int, signed long long, signed long long int**
`unsigned long long`	Same as **`long long`**, but `unsigned`.	▪ Can store integers in the range: 0 ~ 18446744073709551615 (2^{64}) portably.	**unsigned long long int**

[Long long int type program example]

C BASIC (DATA) TYPES

- A sample output.

C:\WINDOWS\system32\cmd.exe

```
long long value is -10000 with 8 bytes in size.
long long int value is 200000 with 8 bytes in size.
signed long long value is -3000000 with 8 bytes in size.
signed long long int value is 40000000 with 8 bytes in size.
unsigned long long value is 500000000 with 8 bytes in size.
unsigned long long int value is 12345678 with 8 bytes in size.
Press any key to continue . . .
```

C BASIC (DATA) TYPES

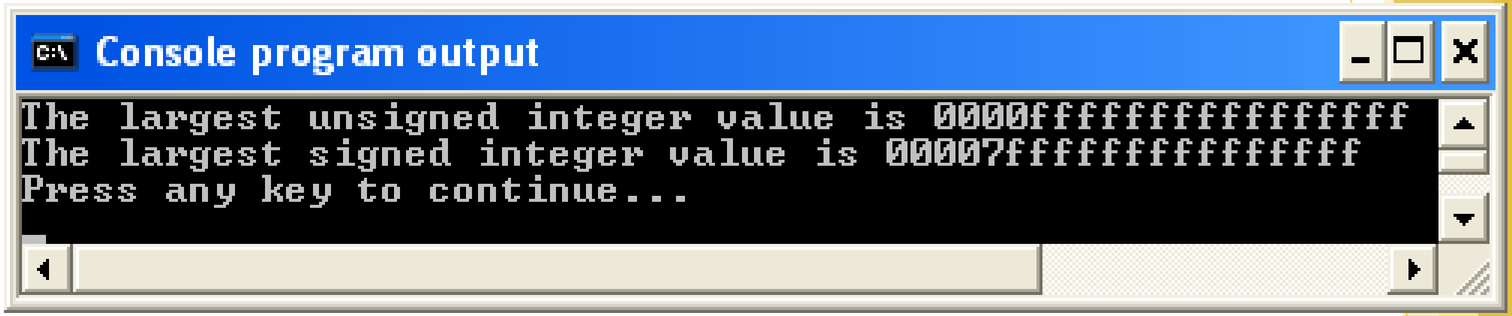
`intmax_t`	Signed integer types capable of representing any value of any signed integer type.	▪ It is a `typedef` represents the signed integer type with largest possible range. ▪ If you want an integer with the widest range possible on the platform on which it is being used.	—
`uintmax_t`	Unsigned integer types capable of representing any value of any unsigned integer type	▪ It is a `typedef` represents the unsigned integer type with largest possible range. ▪ If you want an integer with the widest range possible on the platform on which it is being used.	—

Not supported by MSVC++ < 2012

Program example

C BASIC (DATA) TYPES

- A sample output.



C BASIC (DATA) TYPES

- Unfortunately this is not supported by MSVC++ < 2012
- `inttypes.h` vs. `stdint.h`: The C99 standard says that `inttypes.h` includes `stdint.h`, so there's no need to include stdint.h separately in a standard environment.
- Some implementations have inttypes.h but not stdint.h.
- VS/VC++ users may want to use msinttypes.
- Other references,
  1. http://www.qnx.com/developers/docs/6.5.0/index.jsp?topic=/com.qnx.doc.dinkum_en_c99/stdint.html
  2. http://pubs.opengroup.org/onlinepubs/007904975/basedefs/stdint.h.html
  3. http://publib.boulder.ibm.com/infocenter/iseries/v7r1m0/index.jsp?topic=%2Frtref%2Fstdinth.htm

C BASIC (DATA) TYPES

- Actual size of integer types varies by implementation: Windows, Linux, BSD etc.
- The only guarantee is that the `long long` is not smaller than `long`, which is not smaller than `int`, which is not smaller than `short`.

`long long` > `long` > `int` > `short`

- `int` should be the integer type that the target processor is most efficient working with. For example, all types can be 64-bit.
- Actual size of floating point types also varies by implementation.
- The only guarantee is that the `long double` is not smaller than `double`, which is not smaller than `float`.

`long double` > `double` > `float`

- The 32-bit and 64-bit IEEE 754 floating point formats should be used.

C BASIC (DATA) TYPES

Boolean type

- The boolean (true/false) type is `_Bool` defined in stdbool.h
- The stdbool.h type also defines a few useful identifiers as macros: `bool` is defined as `_Bool`, true as `1`, false as `0`.
- Additionally, `__bool_true_false_are_defined` is defined as 1.
- The `_Bool` type and stdbool.h header did not exist in pre-1999 versions of the standard.

bool in VC++ example

bool in Pelles C example

C BASIC (DATA) TYPES

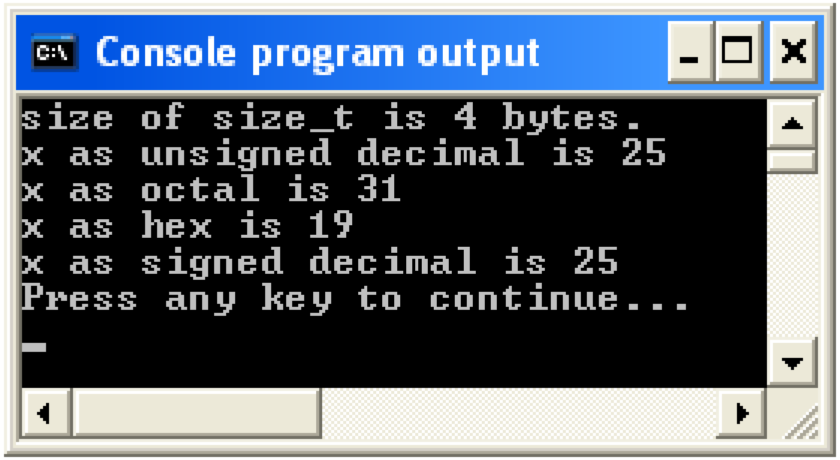
Size and pointer difference types

- Separate `size_t` and `ptrdiff_t` types to represent memory-related quantities.
- Existing types were inadequate, because their size is defined according to the target processor's arithmetic capabilities, not the memory capabilities, such as the address space availability.
- Both of these types are defined in the stddef.h header file (cstddef in C++).
- `size_t` is used to represent the maximum size of any object (including arrays) in the particular implementation.
- An unsigned integer type used to represent the sizes of objects

  size_t program example

C BASIC (DATA) TYPES

- A sample output.



C BASIC (DATA) TYPES

- Used as the return type of the `sizeof()` operator.
- The maximum size of `size_t` is provided via `SIZE_MAX`, a macro constant which is defined in the stdint.h header file (`cstdint` in C++).
- It is guaranteed to be at least `65535`.
- `ptrdiff_t` is used to represent the difference between pointers.
- Is the signed integer type of the result of subtracting two pointers.
- The type's size is chosen so that it could store the maximum size of a theoretically possible array of any type.
- On a 32-bit system `ptrdiff_t` will take 32 bits and on a 64-bit one - 64 bits and it is portable.

size_t and ptrdiff_t: a story

ptrdiff_t program example

C BASIC (DATA) TYPES

- A sample output.

C:\WINDOWS\system32\cmd.exe

```
Value of  of pPointA is 24 and pPointB is 45
Address of pPointA is 12FF48 and pPointB is 12FF3C
The size of ptrdiff_t is 4 bytes
The difference between two pointers is 3 (3)
The difference between two pointers is FFFFFFFD (-3)
Press any key to continue . . .
```

C BASIC (DATA) TYPES

Interface to the properties of the basic types

- Information about the actual properties, such as size, of the basic arithmetic types, is provided via macro constants in two header files,

    1) limits.h header (`climits` in C++) defines macros for integer types.
    2) float.h header (`cfloat` in C++) defines macros for floating-point types.

- The actual values depend on the implementation.

C BASIC (DATA) TYPES

Fixed width integer types

- C99 standard includes definitions of several new integer types to enhance programs' portability.
- Existing basic integer types were considered inadequate; because their actual sizes are implementation defined and may vary across different systems.
- The new types are especially useful in embedded environments where hardware supports limited to several types and varies from system to system.
- All new types are defined in inttypes.h (`cinttypes` in C++) and stdint.h (`cstdint` in C++) header files.
- The types can be grouped into the following categories:

C BASIC (DATA) TYPES

- **Exact width** integer types - are guaranteed to have the same number **N** of bits across all implementations. Included only if it is available in the implementation.
- **Least width** integer types - are guaranteed to be the smallest type available in the implementation, that has at least specified number **N** of bits. Guaranteed to be specified for at least N=8, 16, 32, 64.
- **Fastest** integer types - are guaranteed to be the fastest integer type available in the implementation, that has at least specified number **N** of bits. Guaranteed to be specified for at least N=8, 16, 32, 64.
- **Pointer** integer types - are guaranteed to be able to hold a pointer.
- **Maximum width** integer types - are guaranteed to be the largest integer type in the implementation.

C BASIC (DATA) TYPES

- The following table summarizes the types and the interface to acquire the implementation details (**N** refers to the number of bits).

Type category	Signed types			Unsigned types		
	Type	Min value	Max value	Type	Min value	Max value
Exact width	int**N**_t	INT**N**_MIN	INT**N**_MAX	uint**N**_t	0	UINT**N**_MAX
Least width	int_least**N**_t	INT_LEAST**N**_MIN	INT_LEAST**N**_MAX	uint_least**N**_t	0	UINT_LEAST**N**_MAX
Fastest	int_fast**N**_t	INT_FAST**N**_MIN	INT_FAST**N**_MAX	uint_fast**N**_t	0	UINT_FAST**N**_MAX
Pointer	intptr_t	INTPTR_MIN	INTPTR_MAX	uintptr_t	0	UINTPTR_MAX
Maximum width	intmax_t	INTMAX_MIN	INTMAX_MAX	uintmax_t	0	UINTMAX_MAX

USER DEFINED (DATA) TYPES

Keyword	Size	Note
`struct`	≥ sum of size of each member	An aggregate type which can contain more than one different types.

tag or label is optional

```
struct theEmployee {
              int age;
              double salary;
              char department;
              char name[15];
              char address[5][25];
          };
struct theEmployee workerRec;
```

```
typedef struct
{
    int x;
    int SomeArray[100];
} MyFoo;

int main()
{
    MyFoo strctVar;

    return 0;
}
```

```
struct newPoint {
    short xPoint;
    short yPoint;
} justPoint;

justPoint thePoint;
```

USER DEFINED (DATA) TYPES

`union`	≥ size of the largest member	An aggregate type which can contain more than one other types. `union` uses <u>shared memory space</u> compared to `struct`, so only one member can be accessed at one time.

```
union someData
{
    int  pNum;
    float qNum;
    double rNum;
};
union someData simpleData;
```

```
union OtherData{
   char aNum;
   int xNum;
   float fNum;
} simpleData;
simpleData saveData;
```

USER DEFINED (DATA) TYPES

<table>
<tr><td><code>enum</code></td><td>≥ size of <code>char</code></td><td>Enumerations are a separate type from <code>ints</code>, though they are mutually convertible. Used to declare identifiers as constants in an ordered manner.</td></tr>
<tr><td colspan="3"><pre>enum ndays {Mon, Tue, Wed, Thu, Fri, Sat, Sun};

/ * Creates enum days type, which the identifiers are set
    automatically to the integers 0 to 6. */
enum ndays ndayCount;</pre></td></tr>
<tr><td colspan="2"><pre>enum trafficDirection{
   north,
   south,
   east,
   west
  };

enum trafficDirection newDirection;</pre></td><td><pre>enum cColor = {red = 2,
green, blue, black};

Enum cColor ccolorCode;</pre></td></tr>
</table>

USER DEFINED (DATA) TYPES

typedef	same as the type; being given a new name	**typedef** used to give new identifier names or alias (to simplify the long identifier names), normally used for aggregate defined types.

```
typedef unsigned char BYTE; /* Declares BYTE to be a synonym for unsigned char */
typedef float FLOAT; /* Declares FLOAT (uppercase letter) to be a synonym for unsigned float
(lowercase) */
```

tag or label is optional

```
typedef struct simpleData
 {     int nData;
    char cData;
} newNameType;
```

Or

```
typedef struct {     int nData;
char cData;} newNameType;
newNameType strctType;
```

```
typedef struct TOKEN_SOURCE {
  CHAR     SourceName[8];
  LUID     SourceIdentifier;
} TOKEN_SOURCE, *PTOKEN_SOURCE;

TOKEN_SOURCE newToken;
```

```
typedef union unData{
     double lngSalary;
     int nDay;
}newUntype;

newUnType lntotalSalary;
```

```
typedef enum DayNames { Monday,
                        Tuesday,
                        Wednesday,
                        Thursday,
                        Friday, Saturday, Sunday
           } Weekdays;
Weekdays dayOfWeek;
```

DERIVED (DATA) TYPES

Type	Size	Note
`type*` (a pointer)	$\geq$ size of **`char`**	▪ Hold the memory address which point to the actual data/value. ▪ `0` address always represents the <u>null pointer</u> (an address where no data can be placed), irrespective of what bit sequence represents the value of a <u>null pointer</u>. ▪ Pointers to different types will have different sizes. So they are not convertible to one another. ▪ Even in an implementation which guarantees all data pointers to be of the same size, function pointers and data pointers are in general incompatible with each other. ▪ For functions taking a variable number of arguments, the arguments passed must be of appropriate type.

`char *ptoChar;`
`char csimpleChr = 'T';`
`char *chptr;`
`// assignment`
`chptr = &csimpleChr;`
		`int iNumber = 20;`
		`int *imyPtr = &iNumber;`

DERIVED (DATA) TYPES

`type [integer]` (an array)	≥ integer × size of type	▪ Use to declare a variable with collection of identical properties or types. ▪ Simplify variable declaration. ▪ In a declaration which also initializes the array (including a function parameter declaration), the size of the array (the integer) can be omitted, which is called unsized. ▪ type [ ] is not the same as type*. Only under some circumstances one can be converted to the other.

`int fstudentNumber[3] = {4,7,1};`
`int nrowandColumn[1][2] = {34, 21};`
`int nlongHeightWidth[3][4][5] = 0;`
		`char cName1[ ] = {'a','r','r','a','y'};`
		`char cName2[ ] = {"array"};`
		`char cName3[6] = "array";`
		`int nrowCol[2][3] = {4,2,3,7,2,8};`

DERIVED (DATA) TYPES

type (comma-delimited list of types/declarations) (a function pointers)	—	▪ allow referencing functions with <u>a particular signature</u>. ▪ Function pointers are invoked by <u>name</u> just like normal function calls. Function pointers are separate from pointers and `void` pointers.

```
/* two arguments function pointer  */
int (* fptr) (int arg1, int arg2)

/* to store the address of the standard
   function stdFunct in the variable myIntFunct */
int (*myIntFunct)(int) = stdFunct;
```

End of the C data types