CSCE 4114
bit twiddling (bashing) in C

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Bit Twiddling in C

- C was developed for writing operating systems, it is close to the machine
- Can Address specific memory locations
  - Can move data between memory and registers
  - Can declare register variables
- Basic data types of machine
  - Based on original Data Types of Target Mainframe
  - Needed for OS interactions with device's registers
- Operators included to manipulate single bits within these data types

Data Types

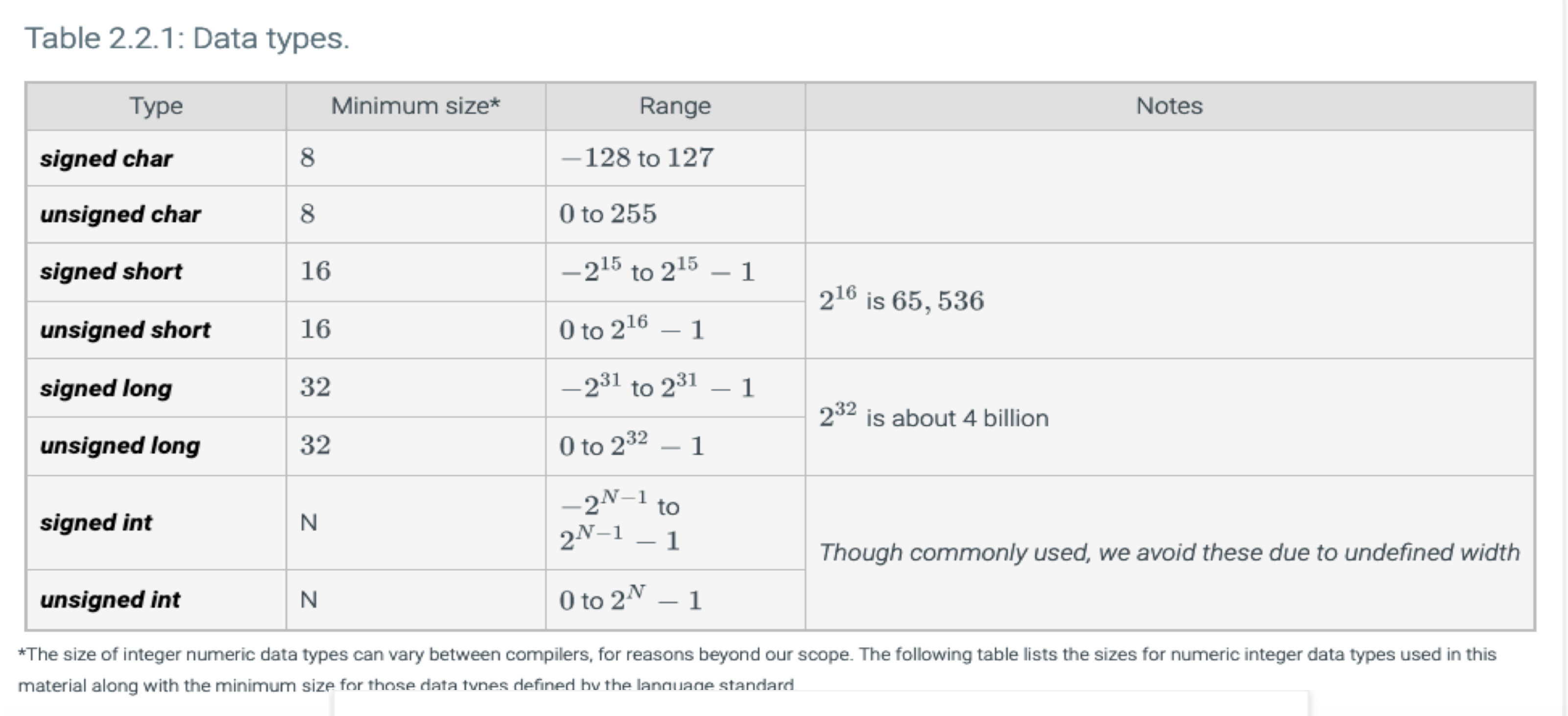

Table 2.2.1: Data types.

Type	Minimum size*	Range	Notes
signed char	8	-128 to 127	
unsigned char	8	0 to 255	
signed short	16	-2^{15} to $2^{15} - 1$	2^{16} is $65,536$
unsigned short	16	0 to $2^{16} - 1$	
signed long	32	-2^{31} to $2^{31} - 1$	2^{32} is about 4 billion
unsigned long	32	0 to $2^{32} - 1$	
signed int	N	-2^{N-1} to $2^{N-1} - 1$	*Though commonly used, we avoid these due to undefined width*
unsigned int	N	0 to $2^{N} - 1$	

*The size of integer numeric data types can vary between compilers, for reasons beyond our scope. The following table lists the sizes for numeric integer data types used in this material along with the minimum size for those data types defined by the language standard

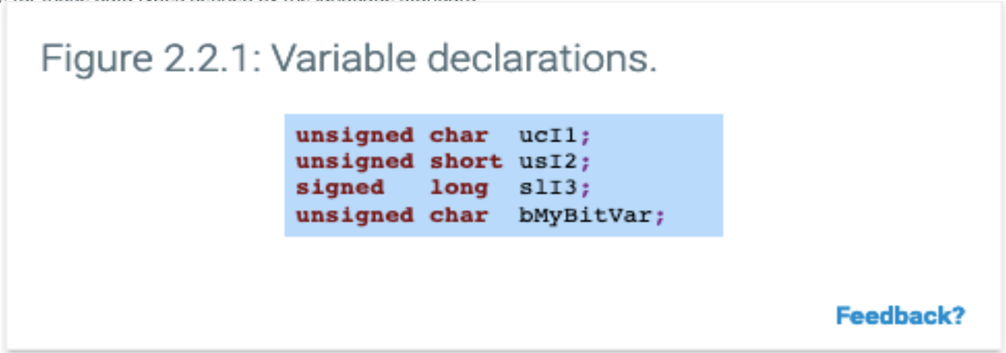

Figure 2.2.1: Variable declarations.

```
unsigned char  ucI1;
unsigned short usI2;
signed   long  slI3;
unsigned char  bMyBitVar;
```

Feedback?

Bit Manipulation

- C has standard bit-manipulation operators.

  & Bit-wise AND

  | Bit-wise OR

  ^ Bit-wise XOR

  ~ Negate (one's comp)

  >> Right-shift

  << Left-shift

```
a |= 0x4; /* Set bit 2 */
d ^= (1 << 5); /* Toggle bit 5 */

g <<= 2; /* Multiply g by 4 */
e >>= 2; /* Divide e by 4 */
```

What do these do ?

```
b &= ~0x4;
c &= ~(1 << 3);
```

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b &= ~0x4; /* Clear bit 2 */

c &= ~(1 << 3); /* Clear bit 3 */

Usage

base_addr = 0x00000400

i/o	i/o	i/o	i/o	i/o	i/o	i/o	i/o

- Suppose you have a Control Register that sets directions for 8 input/output devices
- 1 := input
- 0 := output
- Device is already configured, and you want to check device #2.
- Write down the code in C…………

Usage

base_addr = 0x00000400

i/o	i/o	i/o	i/o	i/o	i/o	i/o	i/o

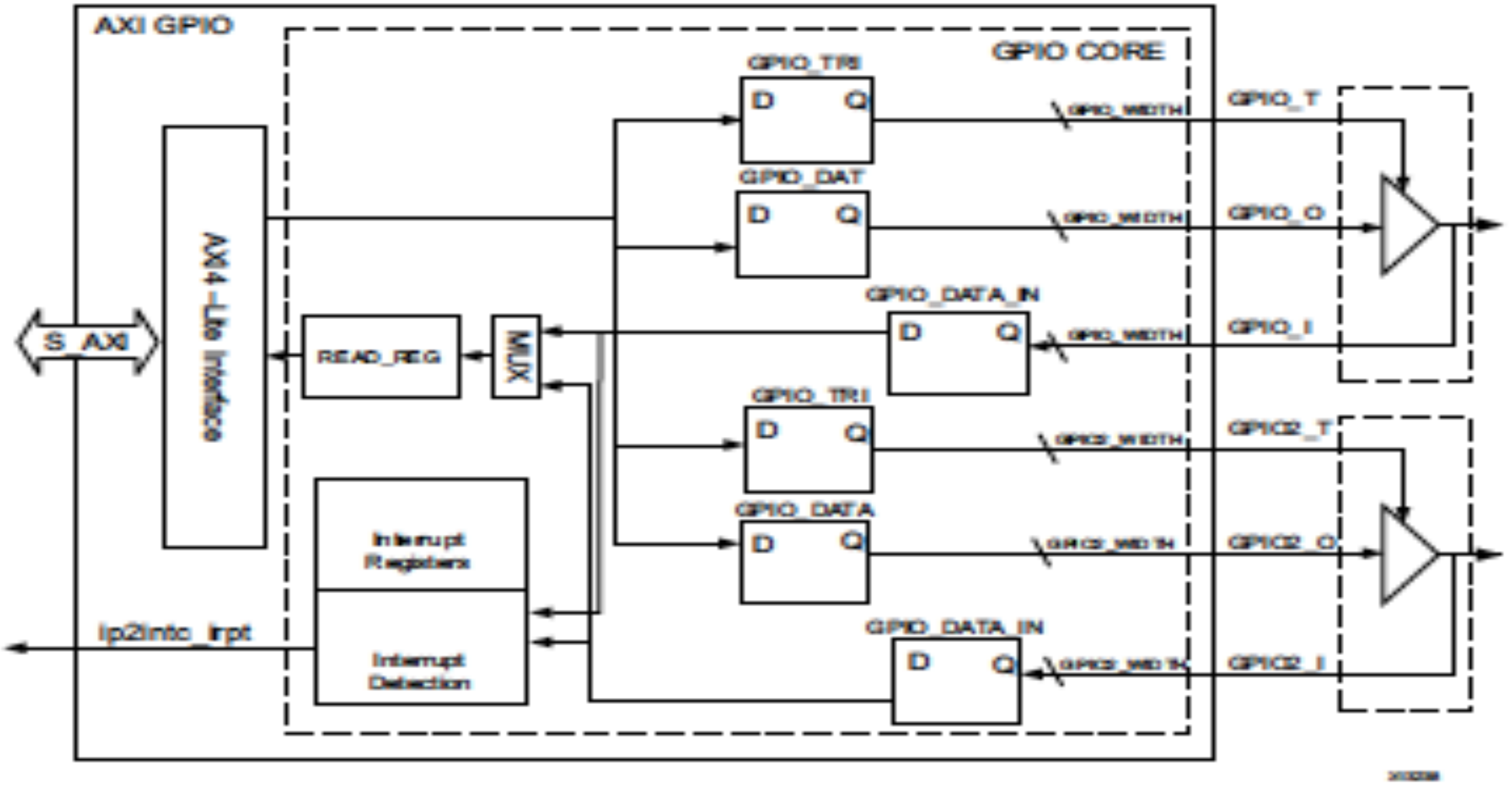
- Suppose you have a Control Register that sets directions for 8 input/output devices
- 1 := input
- 0 := output
- Device is already configured, and you want to check device #2.

```
int mask = 0x4;              /* 00000100 */
A = *base_addr & mask;      /*A only has bit 2 */
```

GPIO Examples

- GPIO := General Purpose Input/Output Core
  - Provides all signals/connections to AXI bus
    - AXI (A)dvanced e(X)tensible (I)nterface
    - Part of ARM Advanced Microcontroller Bus Arch (AMBA)
  - Can Have 1 or 2 Channels of 32 bits each
  - Each bit can be configured as input/output or tri-state

Schematic (Hardware Perspective)



Registers (Programmers Perspective)

- GPIO_TRI := sets up direction and use of Tri-State
  - 0 := write (output) (also turns on tristate connections)
  - 1 := read (input) (disables tristate connections)
    - Tri-state or dedicated input/output pins set during system build

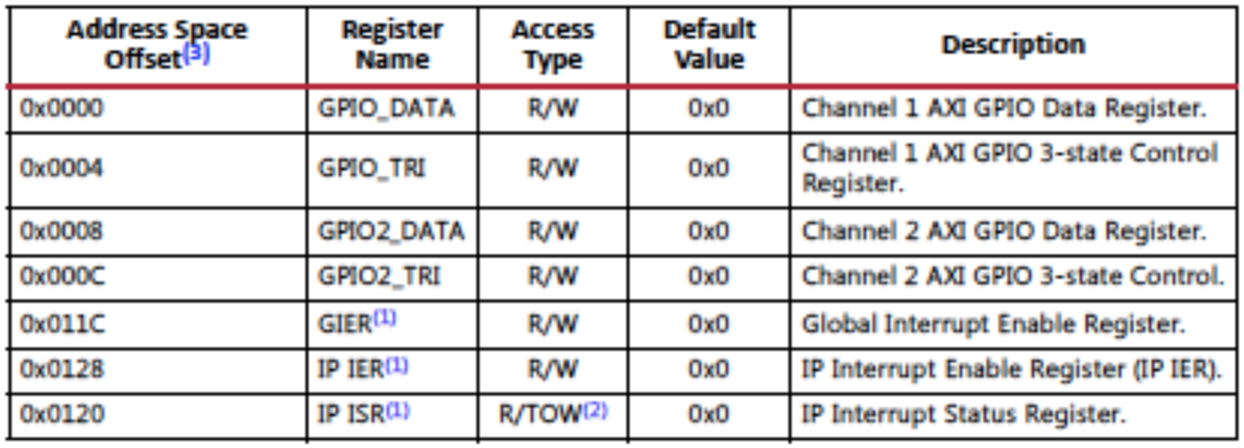


Table 2-4: **Registers**

Address Space Offset[3]	Register Name	Access Type	Default Value	Description
0x0000	GPIO_DATA	R/W	0x0	Channel 1 AXI GPIO Data Register.
0x0004	GPIO_TRI	R/W	0x0	Channel 1 AXI GPIO 3-state Control Register.
0x0008	GPIO2_DATA	R/W	0x0	Channel 2 AXI GPIO Data Register.
0x000C	GPIO2_TRI	R/W	0x0	Channel 2 AXI GPIO 3-state Control.
0x011C	GIER[1]	R/W	0x0	Global Interrupt Enable Register.
0x0128	IP IER[1]	R/W	0x0	IP Interrupt Enable Register (IP IER).
0x0120	IP ISR[1]	R/TOW[2]	0x0	IP Interrupt Status Register.

Data Port

- GPIOx_Data := Port for Data
  - If a bit configured as Output:
    - Writing to it will output the data
    - Bit cannot be read
  - If a bit configured as Input
    - Reading will bring in value
    - Writing to it won't do anything

Example Code Use

```
/* Push buttons are used to control the on-board LEDs. */
// Direction Masks
#define outputDir   0x00000000     // All output bits
#define inputDir     0x0000001F     // 5-input bits

int main()
{
  // Pointer defintions for Button GPIO
  //  ** NOTE - integer definition causes
  //    offsets to be automatically be multiplied by 4!!
  volatile int *base_buttonGPIO          = (int*)(0x40040000);
  volatile int *data_buttonGPIO          = (int*)(base_buttonGPIO + 0x0);
  volatile int *tri_buttonGPIO           = (int*)(base_buttonGPIO + 0x1);

  // Pointer defintions for LED GPIO
  //  ** NOTE - integer definition causes
  //      offsets to be automatically  be multiplied by 4!!
  volatile int *base_ledGPIO             = (int*)(0x40000000);
  volatile int *data_ledGPIO             = (int*)(base_ledGPIO + 0x0);
  volatile int *tri_ledGPIO              = (int*)(base_ledGPIO + 0x1);
// Variable used to store the state of the buttons
  int data = 0;

// Init. the LED peripheral to outputs
  print("Init. LED GPIO Data Direction...\r\n");
  *tri_ledGPIO = outputDir;

  // Init. the Button peripheral to inputs
  print("Init. Button GPIO Data Direction...\r\n");
  *tri_buttonGPIO = inputDir;

  // Infinitely Loop...
  while(1)
    {  // Read the current state of the push buttons
       data = *data_buttonGPIO;
       xil_printf("buttonState = %d\r\n",data);

       // Set the state of the LEDs
       *data_ledGPIO = data; }
  return 0;
}
```