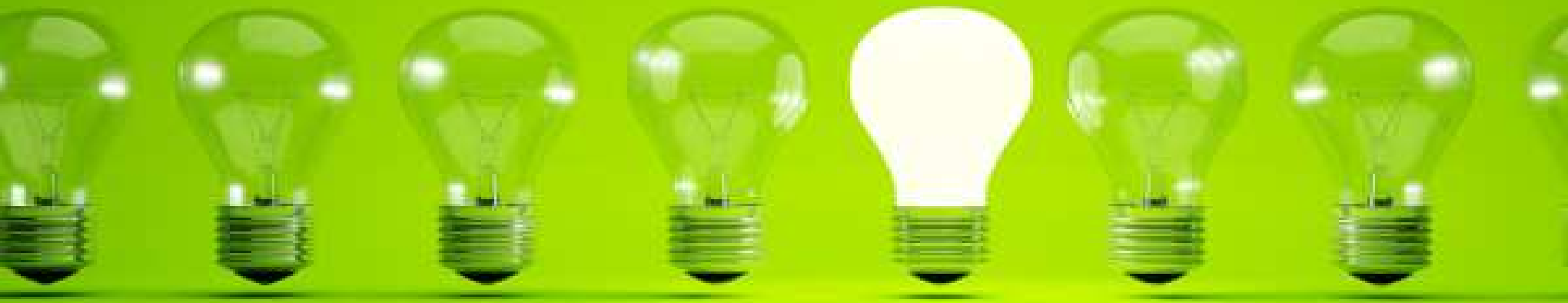
Bit Twiddling



Topics

1) What are the bitwise operators?
2) What is a bit flags and masks?
3) How to:
    a) Read / set single bits.
    b) Read / set multiple bits.
4) Can C access bits better than just bitwise?

Bitwise and Bitmasks

- Bitwise operators
  - | is OR - Set selected bits
  - & is AND -..
  - ~ is NOT - Invert all bits
  - ^ is XOR - Invert selected bits.
- Bit Flags
  - Store multiple binary conditions in a multi-bit value.
  - Ex: encoding the state of 8 LEDs in one char.
- Mask
  - Used to..
  - Has all 1's for bits of that field; 0 elsewhere.

Running Example

- STAT: GPIO Status Reg

Bit	15	14	13	12	11	10	9	8
	LED3	LED2	LED1	LED0	BTN3	BTN2	BTN1	BTN0
R or W	R/W	R/W	R/W	R/W	R	R	R	R

Bit	7	6	5	4	3	2	1	0
	SPD2	SPD1	SPD0	-	-	-	-	FLASH
R or W	R/W	R/W	R/W	R	R	R	R	R/W

- LEDx: Set (1) when on
- BUTTONx: Read 0 when pressed; 1 otherwise.
- SPD2-0: Flash speed; between 0 (slow) and 7 (fast)
- FLASH: 1 means flashing; 0 means solid (on).

Running Example

Bit	15	14	13	12	11	10	9	8
	LED3	LED2	LED1	LED0	BTN3	BTN2	BTN1	BTN0

Bit	7	6	5	4	3	2	1	0
	SPD2	SPD1	SPD0	-	-	-	-	FLASH

- What does this value mean? 0xC2A7

BIT Numbers and Masks

- Bit Numbers
  - #define LED3_BIT 15
    #define LED2_BIT 14
    ...
  - #define BTN3_BIT 11
    ...
  - #define SPD2_BIT 7
    #define SPD1_BIT 6
    #define SPD0_BIT 5
  - #define FLASH_BIT 0
- Convert Bit Number to Mask
  - #define LED0_MASK (1 << LED0_BIT)

Reading a Bit

- Read an LED State
  - _Bool isLed0On = ..
- Read a Button State
  - _Bool isBtn0Pressed = ..
- As Macros
  - #define IS_LED_ON(pin) \
    (STAT & (1 << (pin)) != 0)
  - #define IS_BUTTON_PRESSED(pin) \
    (STAT & (1 << (pin)) == 0)

Reading Bits

- Read Multiple Bits
  - #define LED_MASK 0xF000;
  - _Bool isAnyLEDOn = ..
  - _Bool areAllLEDsOn = ..
- Read Multiple Active-Low Bits
  - #define BTN_MASK 0x0F00
  - _Bool isAnyButtonPressed = ..
  - _Bool areAllButtonsPressed =
    (STAT & BTN_MASK) == 0;

Drive Bits

- Turn on LED 2
  STAT..
- Turn off LED 2
  STAT..
- Turn off LEDs 1 and 2
  STAT &= ~(1<<LED2_BIT | 1<<LED1_BIT);
- Turn on / off all LEDs
  STAT |= LED_MASK;
  STAT &= ~LED_MASK;
- Turn off all LEDs but LED2 (leave it)
  STAT..

Toggle Bits

- // Toggle LED0:
  STAT
- // Toggle all LEDs:
  STAT ^= LED_MASK;

Multi-Bit Fields

- Read value
  - #define SPD_MASK 0x00E0
    int speed =

- Set value
  - void setFlashSpeed(int speed) {
        int newSpeed = (speed << SPD0_BIT)
                & SPD_MASK;
        STAT = (STAT & ~SPD_MASK) | newSpeed;
    }

Explain!

Common Errors

- ~ vs !, & vs &&, | vs ||
- &= vs &= ~(..)
- bit # vs mask: LED1_BIT vs (1<<LED1_BIT)

- use (1<<x) not pow(2,x)
- use (1<<x) | (1<<y), not 1 << (x | y)
- b &= ~(1<<x) is not b = ~(1<<x)
- (a & ~b) is not (~a & b)

Real World Example: ATMEL CAN128

8-bit Timer/Counter Register Description

Timer/Counter2 Control Register A– TCCR2A

Bit	7	6	5	4	3	2	1	0	
	FOC2A	WGM20	COM2A1	COM2A0	WGM21	CS22	CS21	CS20	TCCR2A
Read/Write	W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

- **Bit 7 – FOC2A: Force Output Compare A**

The FOC2A bit is only active when the WGM bits specify a non-PWM mode. However, for ensuring compatibility with future devices, this bit must be set to zero when TCCR2A is written when operating in PWM mode. When writing a logical one to the FOC2A bit, an immediate compare match is forced on the Waveform Generation unit. The OC2A output is changed according to its COM2A1:0 bits setting. Note that the FOC2A bit is implemented as a strobe. Therefore it is the value present in the COM2A1:0 bits that determines the effect of the forced compare.

A FOC2A strobe will not generate any interrupt, nor will it clear the timer in CTC mode using OCR2A as TOP.

The FOC2A bit is always read as zero.

- **Bit 6, 3 – WGM21:0: Waveform Generation Mode**

These bits control the counting sequence of the counter, the source for the maximum (TOP)

Harder Exercises

- Decrement the current speed (SPD) by 1. Don't decrement if already 0.
- Write a function to make it seem like an LED is bouncing back and forth.
- Write a function that does:
  If button N is pressed, turn on LEDs 0 - N.

C-Bit Fields

C Bit-Fields

- Declare fields in a struct with sizes (# bits)
  - Compiler pushes fields together to conserve space.
- Ex:

  Represent a colour with 8 bits each for red, green, blue; and 1 bit for transparent:

```
struct colour_s {
    unsigned int red         : 8;
    unsigned int green       : 8;
    unsigned int blue        : 8;
    unsigned int transparent : 1;
};
```

  - Entire struct needs only one unsigned int (32-bits)

Bit-field Details

- Access fields by name:
  - struct colour_s border = {0xff, 0xff, 0x00, 1}
    printf("Red %d\n", border.red);
  - border.transparent = 1;

    When assigning a value, ensure you don't have more bits that expected
- WARNING:
  The order the fields get packed..
  - Is the first field in the LSB, or is the last field in the LSB?

Code is non-portable: Must retest on new hardware or compiler.

OK for platform specific hardware access; poor for applications needing cross-platform binary data compatibility

STAT Example

```
struct stat_s {
        unsigned int flash : 1;
        unsigned int       : 4;  // Unused bits    ..
        unsigned int spd   : 3;
        unsigned int btn   : 4;
        unsigned int led   : 4;                    ..
};

#define STAT_ADDR 0xC800153C
struct stat_s *pSTAT = (struct stat_s *) STAT_ADDR;

 int main() {
        pSTAT->flash = 1;
        if (pSTAT->btn == 0x0F) {
                pSTAT->spd += 2;
        }
        pSTAT->led = pSTAT->btn;
        return 0;
 }
```

Unnamed fields take up unused space to line fields up as required

Must test to ensure fields don't need to be..