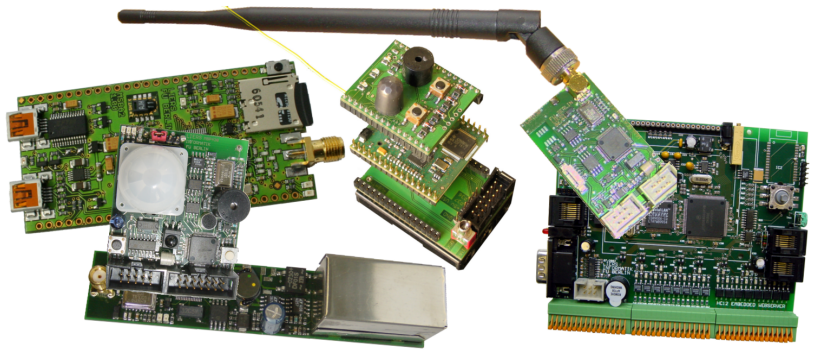

19579 - PR: Programming Wireless Sensor Networks

Introduction

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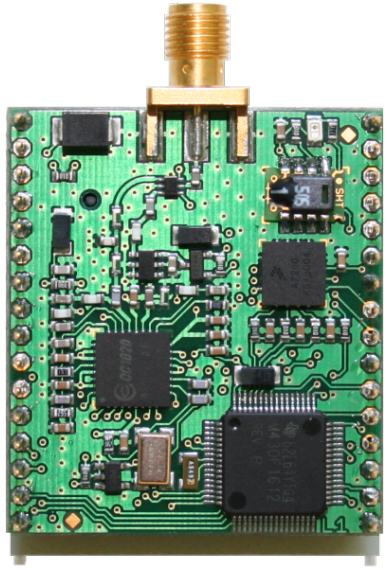
Outline

1. Embedded Systems
2. Hardware
3. Software
4. Toolchain
5. Examples
6. Further Reading

- Slow CPU
- Little RAM and (Flash) ROM Memory
- Mostly no MMU
- Limited energy resources
- FPU might be missing
- Specialized and very basic OS
- Difficult to debug

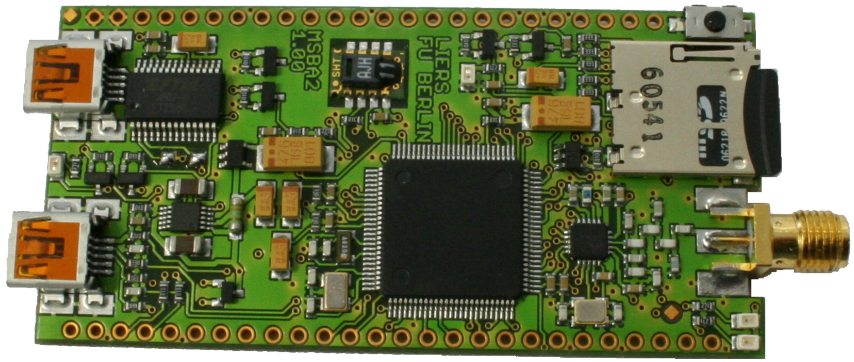


Applications of Wireless Sensor Networks

- home and building automation
- industrial automation
- asset management and logistics
- personal health and fitness
- improved energy efficiency and smart metering
- real-time environmental monitoring
- vehicular automation
- disaster zones, unaccessible or hazardous areas

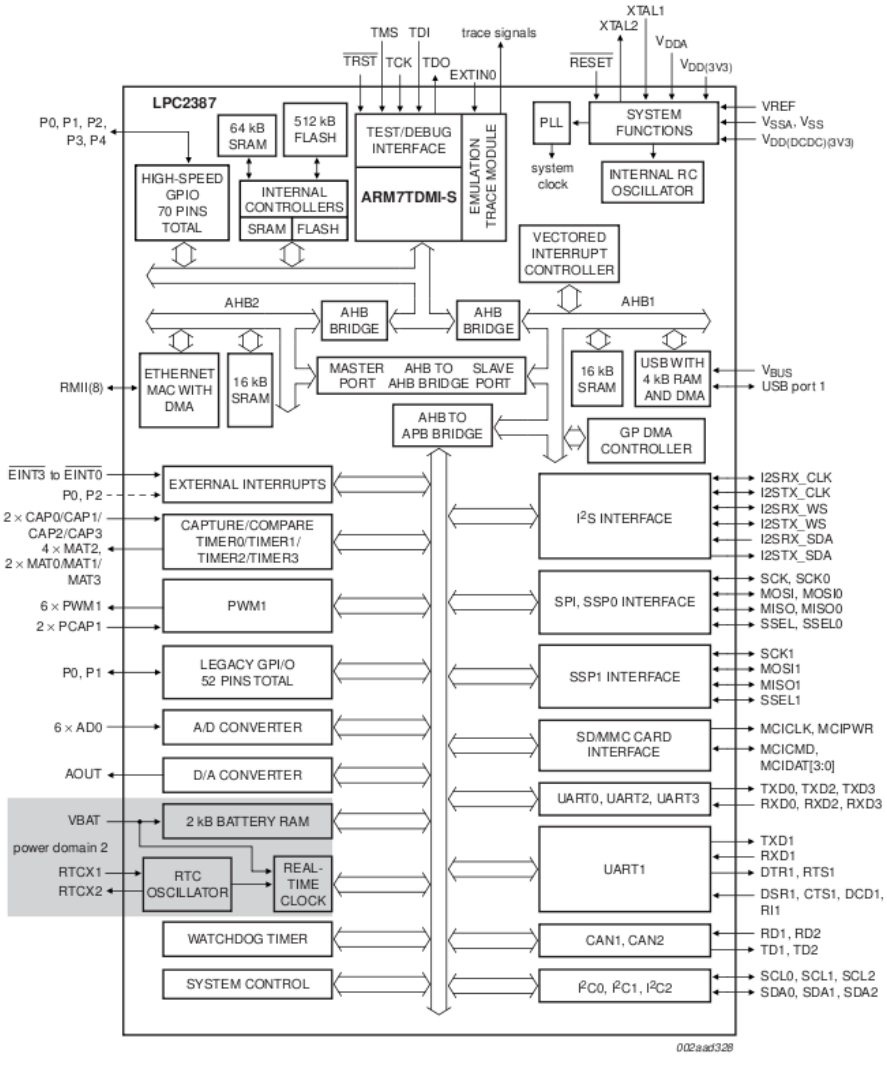
MSB-A2

- ARM 7 microcontroller
- CC1100 radio transceiver @ 868 MHz
- SHT11 temperature and humidity sensor
- Coulomb counter
- Micro SD card holder
- one button
- three LEDs
- two micro USB slave ports
- a lot of free IO pins



LPC2387 - ARM7TDMI-S

- up to 72 MHz
- 32 bit architecture
- 96 kB RAM
- 512 kB ROM
- Real Time Clock
- USB interface
- Ethernet MAC
- 4 UARTS
- SPI interface
- three I^2C interfaces



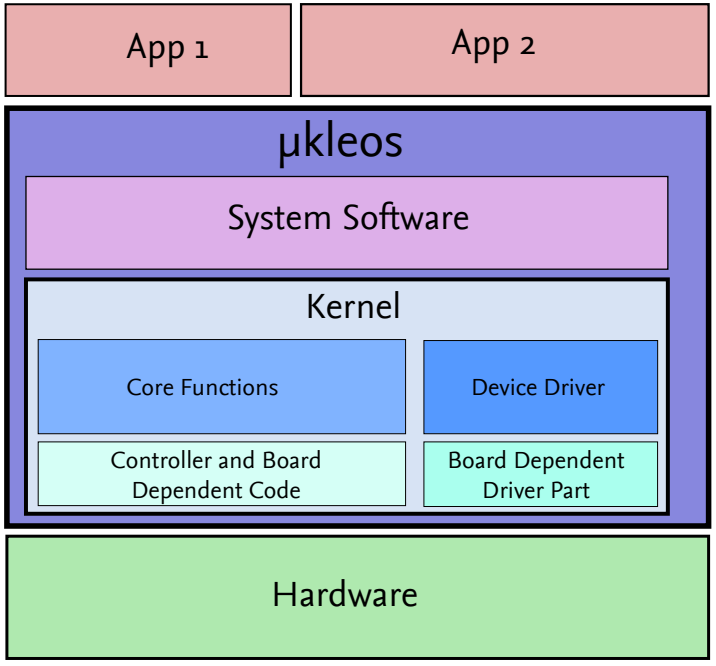
µkleos - Operating System

- Small operation system for microcontrollers
- Microkernel system
- Nonpreemptive scheduler
- Modular design, easy portable
- Existing ports for:
  - MSB-A2
  - MSB-430H
  - eZ430-Chronos
- Documentation needs work

http://www.ukleos.org

Software Architecture

- Application code in /projects/$APP
- System functions in /sys/
- Board independent part of driver code in /driver/$DEVICE
- Board dependent and board dependent driver code in /board/$BOARD
- Controller dependent code in /cpu/$CPU
- Hardware independent core functions (scheduler, messaging, mutexes . . .) in /core/

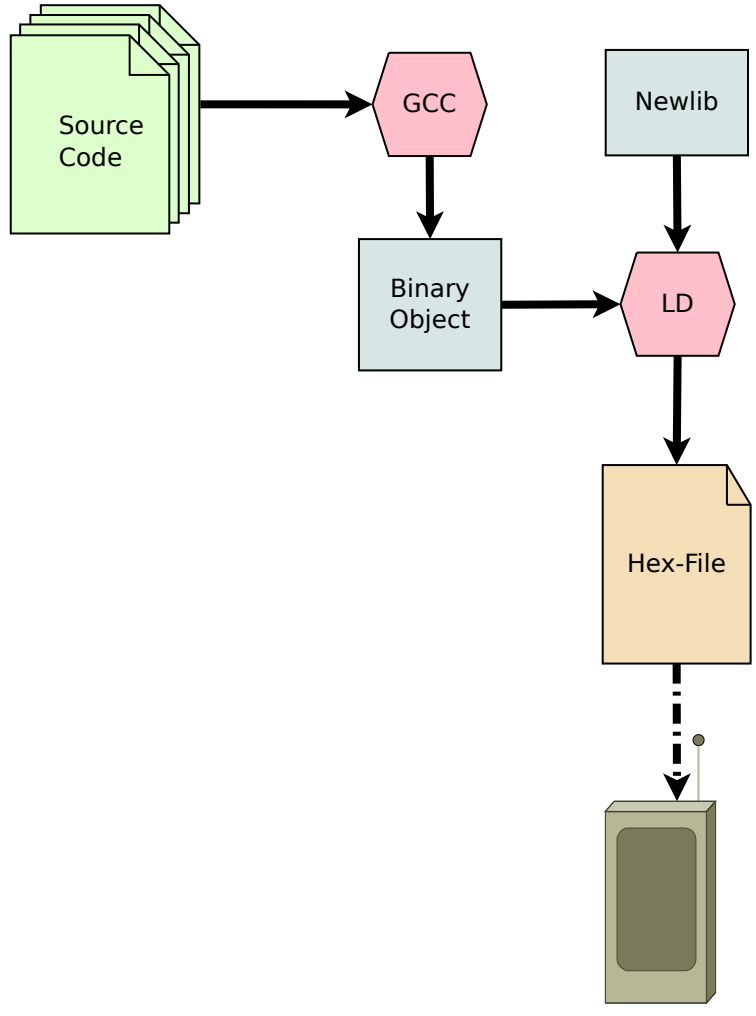


Toolchain

GNU ARM/Newlib toolchain

- GNU binutils
- GNU compiler set (GCC)
- GDB and Insight debugger
- Newlib c library

So generated hex files are programmed onto the microcontroller using serial line and ARM bootloader.



Example 1 - LED blinker


```
#include <stdio.h>
#include <board.h>
#include <hwtimer.h>

int main(void) {
    LED_RED_ON;
    hwtimer_sleep(1000 * 1000);
    printf("Hello World!\n");
    LED_RED_OFF;
    LED_GREEN_ON;

    return 0;
}
```

Example 2 - Timer


```
#define MSEC  (1000)
#define SEC   (1000 * MSEC)

void blinker(void *flag);

swtimer_t t1;

int main(void) {
    hwtimer_init();
    swtimer_init();
    swtimer_usleep(3 * SEC);
    LED_RED_ON;
    swtimer_set_cb(&t1, (3 * SEC), blinker, NULL);
    return 0;
}

void blinker(void *flag) {
    LED_GREEN_TOGGLE;
    LED_RED_TOGGLE;
    swtimer_set_cb(&t1, SEC, blinker, NULL);
}
```

Example 3 - Messaging


```
int main(void) {
    msg m;
    int pid = thread_create(KERNEL_CONF_STACKSIZE_MAIN, PRIORITY_MAIN-1,
                CREATE_WOUT_YIELD | CREATE_STACKTEST, second_thread, "pong");
    m.content.value = 1;
    while(1) {
                msg_send(&m, pid, true);
                msg_receive(&m);
                printf("Got msg with content %i\n", (int) m.content.value);
    }
}

void second_thread(void) {
    msg m;
    while(1) {
        msg_receive(&m);
        printf("2nd: got msg from %i\n", m.sender_pid);
        m.content.value++;
        msg_send(&m, m.sender_pid, true);
    }
}
```

Example 4 - Sensor reading


```
int main(void)
{
    sht11_val_t sht11_val;
    uint8_t success = 0;

    hwtimer_init();
    swtimer_init();
    sht11_init();
    while (1) {
        success = sht11_read_sensor(&sht11_val, HUMIDITY | TEMPERATURE);
        if (success) {
            printf("%-6.2f°C %5.2f%% (%5.2f%%)\n",
                    sht11_val.temperature,
                    sht11_val.relhum,
                    sht11_val.relhum_temp);
        }
        LED_RED_TOGGLE;
        swtimer_usleep(1000 * 1000);
    }
}
```

Further Reading

- **Embedded Programming**
  - J. Wiegelmann, Softwareentwicklung in C für Mikroprozessoren und Mikrocontroller, Hüthig, 2009
  - A. Sloss, D. Symes, C. Wright, ARM System Developer's Guide, Elsevier, 2004
- **General**
  - I. Akyildiz, Wireless Sensor Networks, Wiley, 2010
  - A. Tanenbaum, Modern Operating Systems, Pearson Education, 2007
  - B. Kernighan, D. Ritchie, C Programming Language, Prentice Hall International, 1988

End of the First Steps