# ATTEMPT TO DESIGN A REAL TIME OPERATING SYSTEM

Github Link for the Project:

https://github.com/lazyswan/Kernel_Components

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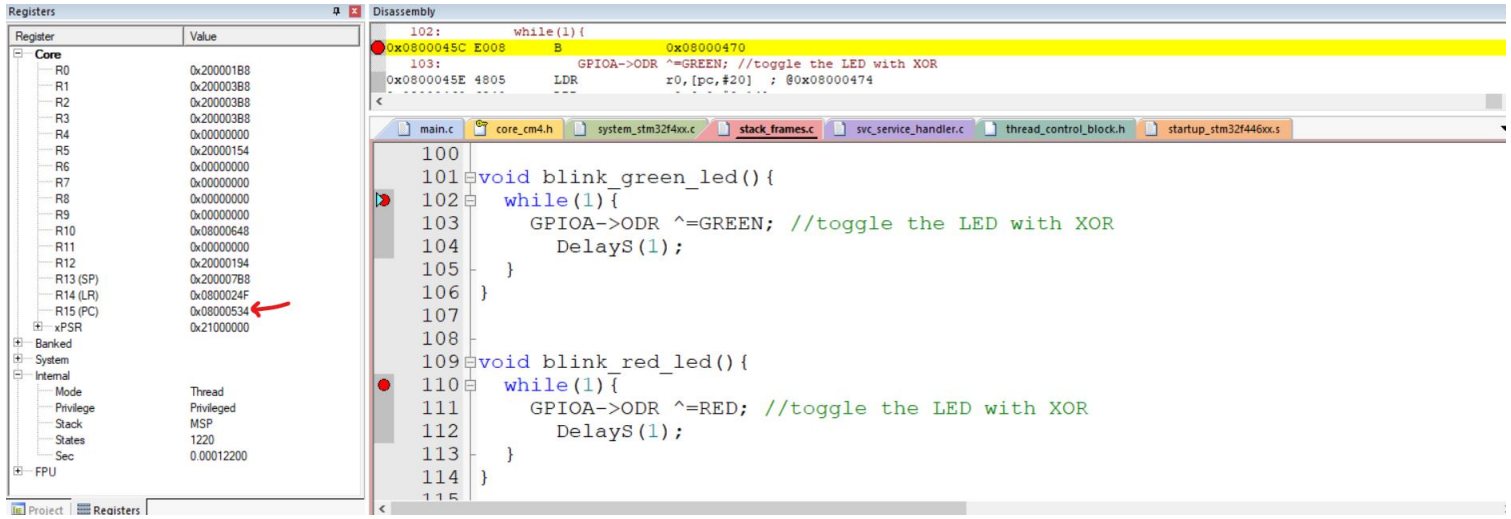
# CRAPPY WAY OF TASK-SWITCH

Address of Thread blink_green_led() : 0x0800045C

Address of Thread blink_red_led() : 0x08000478

Load PC with one of this address to perform switch,

But its not context switch, since we are not switching context(registers) just the PC and program might crash.



# INITIALISING STACK FRAMES AND CHANGING SP IN ISR_HANDLER

Disassembly

```
159:        _tick=tick;
```

main.c | core_cm4.h | system_stm32f4xx.c | stack_frames.c | svc_service_handler.c | thread_control_block.h | startup_stm32f446xx.s

```
121   *(--sp_green_stack)= (uint32_t)&blink_green_led; //PC-->FUNCTIONAL POinter
122   *(--sp_green_stack)= (uint32_t)(0X0000000CU);//LR
123   *(--sp_green_stack)= (uint32_t)(0X00000000U);//R12
124   *(--sp_green_stack)= (uint32_t)(0X0000000FU);//R3
125   *(--sp_green_stack)= (uint32_t)(0X0000000FU);//R2
126   *(--sp_green_stack)= (uint32_t)(0X0000000EU);//R1
127   *(--sp_green_stack)= (uint32_t)(0X0000000EU);//R0
128
129   //Stack Frame for Red_Blink_Function(Context of That Thread)
130   *(--sp_red_stack)=(1U<<24); //xPSR
131   *(--sp_red_stack)=(uint32_t) &blink_red_led; //PC
132   *(--sp_red_stack)=(0x0000000BU); //LR
133   *(--sp_red_stack)=(0x0000000EU); //R12
134   *(--sp_red_stack)=(0x0000000DU); //R3
135   *(--sp_red_stack)=(0x0000000EU); //R2
136   *(--sp_red_stack)=(0x0000000AU); //R1
137   *(--sp_red_stack)=(0x0000000DU); //R0
138   blink_green_led();
139   blink_red_led();
140   while(1);
141 }
```

Memory 1

0x20000094

```
0x20000094: 0E 00 00 00
0x20000098: 0E 00 00 00
0x2000009C: 0F 00 00 00
0x200000A0: 0F 00 00 00
0x200000A4: 00 00 00 00
0x200000A8: 0C 00 00 00
0x200000AC: 5D 04 00 08
```

Memory 2

0x20000138

```
0x20000138: 0A 00 00 00
0x2000013C: 0E 00 00 00
0x20000140: 0D 00 00 00
0x20000144: 0E 00 00 00
0x20000148: 0B 00 00 00
```

```
150 //Sys tick handler, ISR executed in everytick intr
151 void SysTick_Handler(){
152   ++tick;
153   //In this handler we change the value of stack pointer to load the
154   //differnt context, custom stack frames.
155
156 }
157
```

# BUILDING KERNEL INTERNALS___ SIMPLE KERNEL WITH JUST 3 THREADS .

Supported Features:

- 3 Threads.
- Round Robin Scheduler.
- Task Yield Functionality to support Co-operative Scheduling
- Semaphore.
- Cooperative Semaphore.

# THREAD CONTROL BLOCK

```
12  #define NUM_OF_THREADS  3
13  #define STACK_SIZE      100
14  #define BUS_FREQ        16000000
15  #define SYSPRI3         (*((volatile uint32_t *)0xE000ED20))
16  #define INTRCTRL        (*((uint32_t volatile *)0xE000ED04))
17
18  void osSchedulerLaunch(void);
19  uint32_t MILLIS_PRESCALAR;
20
21  //Thread Control Block
22  typedef struct tcb{
23    int32_t *sp;    //stack pointer
24    struct tcb *next;
25  }tcb_t;
26
27  //Similar to process descriptor table;
28  //This one is thread descriptor table/Array of TCB.
29  tcb_t tcbs[NUM_OF_THREADS];
30
31  //Holds Pointer to current running Process
32  tcb_t *current_tcb;
33
34  //stack area for all the threads in form of 2-d matrix
35  int32_t TCB_STACK[NUM_OF_THREADS][STACK_SIZE];
36
37  /*
```

# KERNEL STACK INIT

```
36
37  /*
38  Initialses the stack,
39  PC and xPSR for each Thread.
40  thread_num: 0,1,2
41  */
42  void osKernelStackInit(int thread_num){
43
44    //Stack pointer initialised to bottom of its stack.
45    tcbs[thread_num].sp = & TCB_STACK[thread_num][STACK_SIZE-16];
46
47    //Runining in the thumb mode | xpsr rx Bit 24.
48    TCB_STACK[thread_num][STACK_SIZE-1]=1<<24;
49
50  }
51  /*
```

# CREATING THREADS

```
51 /*
52 This function decides which thread to run,
53 this function must be atomic, its critical section
54 */
55 uint8_t osKernelAddThreads(void (*task0)(),void (*task1)(),void (*task2)()){
56
57   //connected all the tcbs in circular LL fashion
58     __disable_irq();
59
60     tcbs[0].next=&tcbs[1];
61     tcbs[1].next=&tcbs[2];
62     tcbs[2].next=&tcbs[0];
63
64   //initialise PC with task0,callback function
65   osKernelStackInit(0);
66   TCB_STACK[0][STACK_SIZE-2]= (int32_t)(task0);
67
68   //initialise PC with task1,callback function
69   osKernelStackInit(1);
70   TCB_STACK[1][STACK_SIZE-2]= (int32_t)(task1);
71
72   //initialise PC with task2,callback function
73   osKernelStackInit(2);
74   TCB_STACK[2][STACK_SIZE-2]= (int32_t)(task2);
75
76   //First Task to be scheduled is task0
77   current_tcb= &tcbs[0];
78   __enable_irq();
79
80
81   return 1;
82 }
```

# KERNEL LAUNCH

```
83  void osKernelInit(){
84
85      __disable_irq();
86      MILLIS_PRESCALAR=BUS_FREQ/1000;
87  }
88
89  void osKernelLaunch(uint32_t quanta){
90      //initialising SysTick
91      SysTick->CTRL=0;
92      SysTick->VAL=0;
93      SYSPRI3 =(SYSPRI3&0x00FFFFFF)|0xE0000000; //priority to 7
94
95      //SysTick Interrupts after @ LOAD value | quanta
96      SysTick->LOAD=(quanta*MILLIS_PRESCALAR)-1;
97
98      SysTick->CTRL = 0x00000007;
99
100     //This is assembly Function
101     osSchedulerLaunch();
102 }
103
```

# TASK YEILD

```
109 void osThreadYeild(){
110
111   //reset the counter value to 0;
112   SysTick->VAL=0;
113   //this will generate a
114   //sysTick Intr and then sysTick Handler will perform a context SW.
115   INTRCTRL= 1<<26;
116
117 }
```

# ASSEMBLY CODE

```
1         AREA |.text|, CODE, READONLY, ALIGN=2
2         THUMB
3         EXTERN  current_tcb
4         EXPORT  SysTick_Handler
5         EXPORT  osSchedulerLaunch
6
7
8   SysTick_Handler          ;save r0,r1,r2,r3,r12,lr,pc,psr
9       CPSID   I                   ;Disables the INTR
10      PUSH    {R4-R11}          ;save r4,r5,r6,r7,r8,r9,r10,r11
11      LDR     R0, =current_tcb  ; R0=current_tcb(which is a pointer
12      LDR     R1, [R0]          ; r1= currentPt
13      STR     SP, [R1]
14      LDR     R1, [R1,#4]       ; r1 =currentPt->next
15      STR     R1, [R0]          ;currentPt =r1
16      LDR     SP, [R1]          ;SP= currentPt->stackPt
17      POP     {R4-R11}
18      CPSIE   I
19      BX      LR
20
21
22
23  osSchedulerLaunch
24      LDR     R0, =current_tcb
25      LDR     R2, [R0]        ; R2 =currentPt
26      LDR     SP, [R2]        ;SP = currentPt->stackPt
27      POP     {R4-R11}
28      POP     {R0-R3}
29      POP     {R12}
30      ADD     SP,SP,#4
31      POP     {LR}
32      ADD     SP,SP,#4
```

# SEMAPHORE

```
4  scsapre@gmail.com
5  */
6
7  #include<stdint.h>
8
9  void osSemaphoreInit(int32_t *semaphore, int32_t value){
10   *semaphore=value;
11 }
12
13 void osSignalSet(int32_t *semaphore){
14   __disable_irq();
15   *semaphore+=1;
16   __enable_irq();
17 }
18
19 void osSignalWait(int32_t *semaphore){
20   __disable_irq();
21   while(*semaphore<=0){
22   __disable_irq();
23   __enable_irq();
24   }
25   *semaphore-=1;
26   __enable_irq();
27 }
```

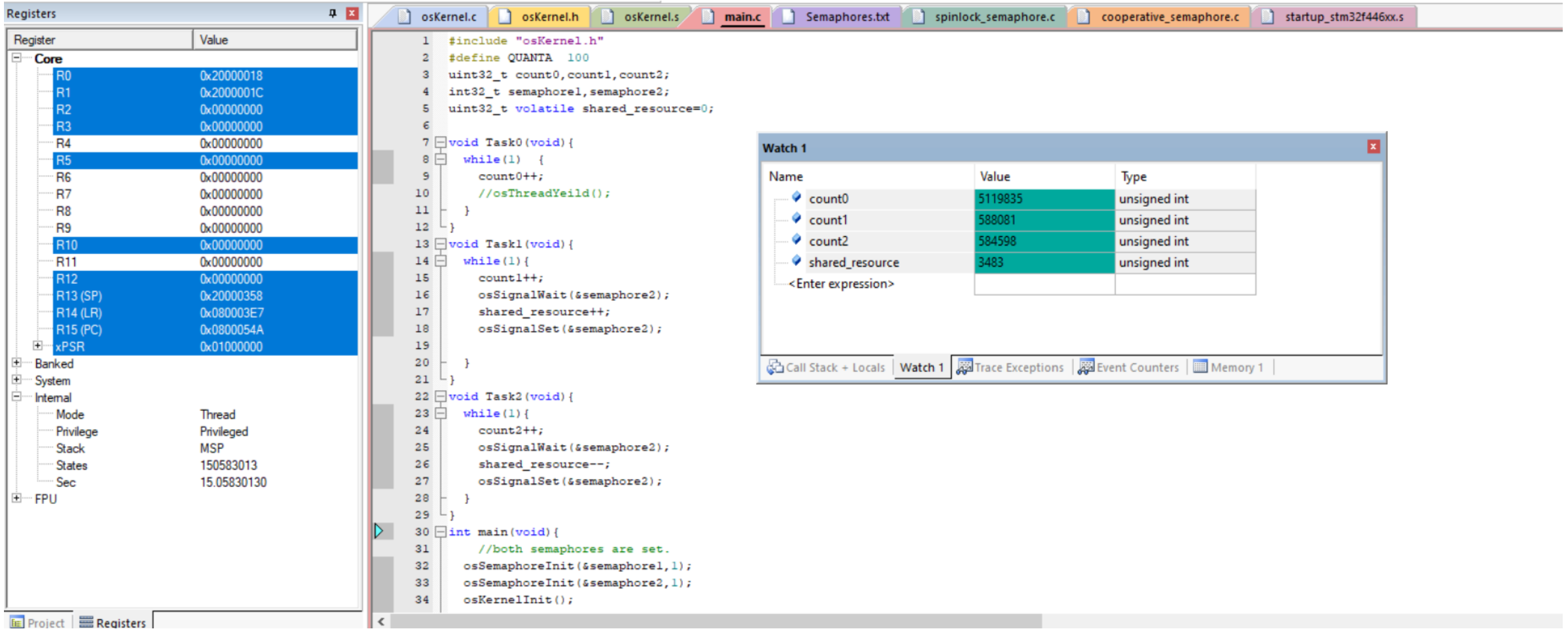
# COOPERATIVE SEM

```
23
24 //instead of busywaiting for entire Quanta, task yeilds to another task
25 void osSignalWait(int32_t *semaphore){
26    __disable_irq();
27    while(*semaphore<=0){
28      __disable_irq();
29      osThreadYeild();
30      __enable_irq();
31
32    }
33    *semaphore-=1;
34    __enable_irq();
35 }
```

# MAIN FUNCTION

```
1  #include "osKernel.h"
2  #define QUANTA  10
3  uint32_t count0,count1,count2;
4  int32_t semaphore1,semaphore2;
5  uint32_t volatile shared_resource=0;
6
7  void Task0(void){
8    while(1)  {
9      count0++;
10     osThreadYeild();
11   }
12 }
13 void Task1(void){
14   while(1){
15     osSignalWait(&semaphore2);
16     shared_resource++;
17     osSignalSet(&semaphore1);
18   }
19 }
20 void Task2(void){
21   while(1){
22     osSignalWait(&semaphore1);
23     shared_resource--;
24     osSignalSet(&semaphore2);
25   }
26 }
27 int main(void){
28   osKernelInit();
29   osKernelAddThreads(&Task0,&Task1,&Task2);
30   osKernelLaunch(QUANTA);
31   //both semaphores are set.
32   osSemaphoreInit(&semaphore1,0);
33   osSemaphoreInit(&semaphore2,1);
34 }
```

# OUTPUT


Registers
Register
Value
Core
R0 0x20000018
R1 0x2000001C
R2 0x00000000
R3 0x00000000
R4 0x00000000
R5 0x00000000
R6 0x00000000
R7 0x00000000
R8 0x00000000
R9 0x00000000
R10 0x00000000
R11 0x00000000
R12 0x00000000
R13 (SP) 0x20000358
R14 (LR) 0x080003E7
R15 (PC) 0x0800054A
xPSR 0x01000000
Banked
System
Internal
Mode Thread
Privilege Privileged
Stack MSP
States 150583013
Sec 15.05830130
FPU
Project
Registers
osKernel.c
osKernel.h
osKernel.s
main.c
Semaphores.txt
spinlock_semaphore.c
cooperative_semaphore.c
startup_stm32f446xx.s
1 #include "osKernel.h"
2 #define QUANTA 100
3 uint32_t count0,count1,count2;
4 int32_t semaphore1,semaphore2;
5 uint32_t volatile shared_resource=0;
6
7 void Task0(void){
8 while(1) {
9 count0++;
10 //osThreadYeild();
11 }
12 }
13 void Task1(void){
14 while(1){
15 count1++;
16 osSignalWait(&semaphore2);
17 shared_resource++;
18 osSignalSet(&semaphore2);
19
20 }
21 }
22 void Task2(void){
23 while(1){
24 count2++;
25 osSignalWait(&semaphore2);
26 shared_resource--;
27 osSignalSet(&semaphore2);
28 }
29 }
30 int main(void){
31 //both semaphores are set.
32 osSemaphoreInit(&semaphore1,1);
33 osSemaphoreInit(&semaphore2,1);
34 osKernelInit();
Watch 1
Name
Value
Type
count0 5119835 unsigned int
count1 588081 unsigned int
count2 584598 unsigned int
shared_resource 3483 unsigned int
<Enter expression>
Call Stack + Locals
Watch 1
Trace Exceptions
Event Counters
Memory 1