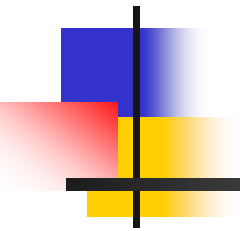
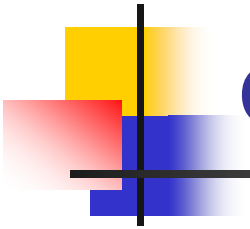


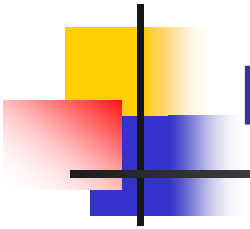
MicroC-OS-II

(synchronization 1)



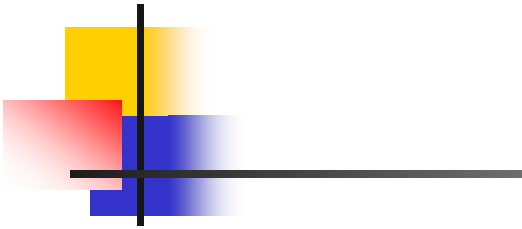
Outline

- Task synchronization
  - **Event control block**
  - **Mailbox**
  - **Message queue**
  - Semaphore
  - Mutex semaphore
  - Event flag



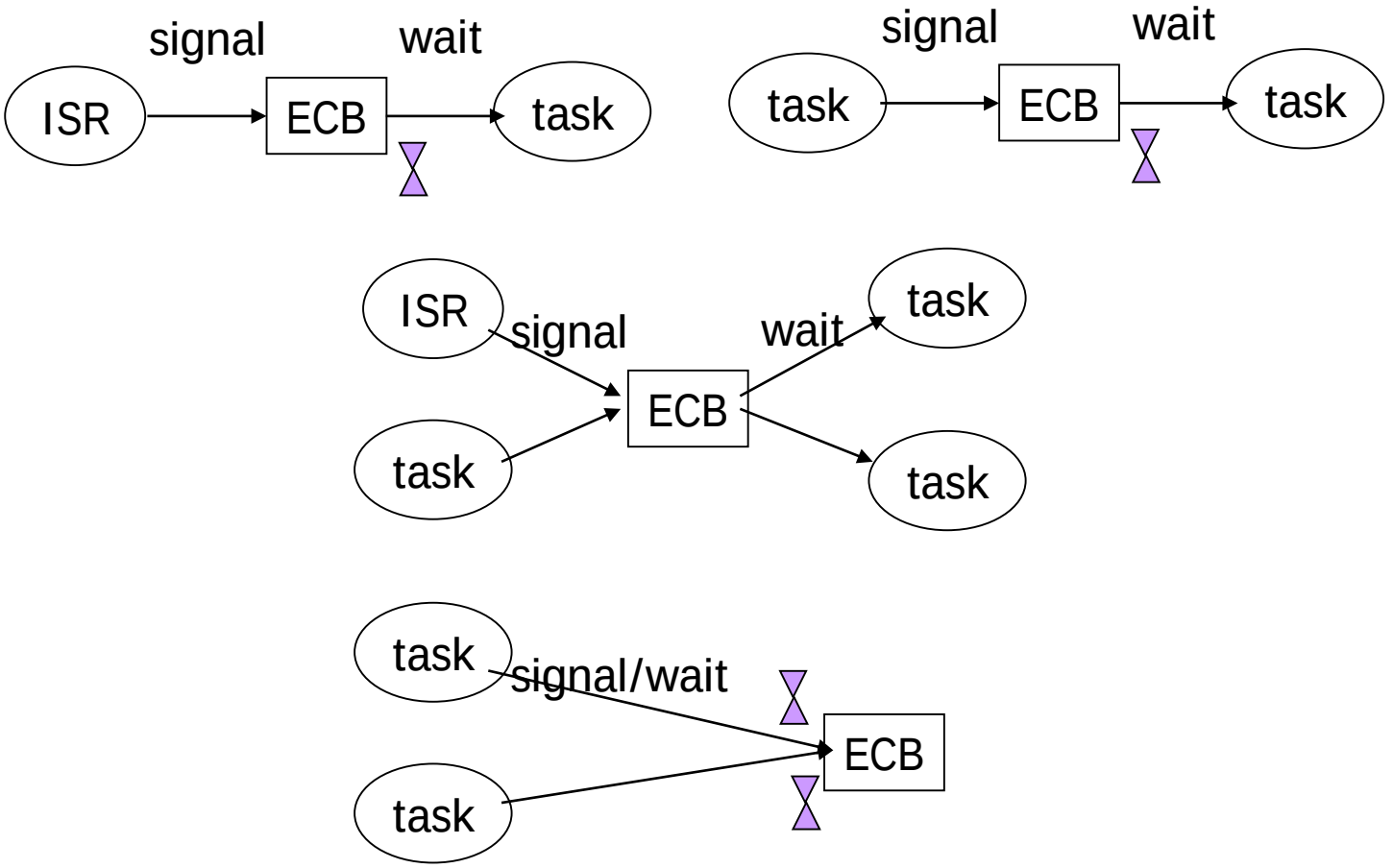
Event control block -overview

- Semaphore, message queue, mailbox
  - OSXXXCreate
  - OSXXXDel
  - OSXXXPend
    - Wait for XXX
  - OSXXXPost
    - Release XXX
  - OSXXXAccept
    - A non-blocking version of OSXXXPend
  - OSXXXQuery



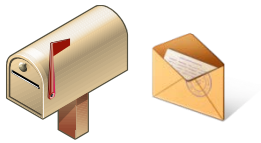
- Semaphores, mutexs, message queues, mailboxes are managed by event control blocks
- For example, a semaphore is created
  - A event control block associated with the semaphore is also created

In other words;



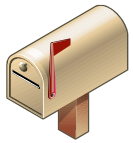
EVENT CONTROL BLOCK

Task 1

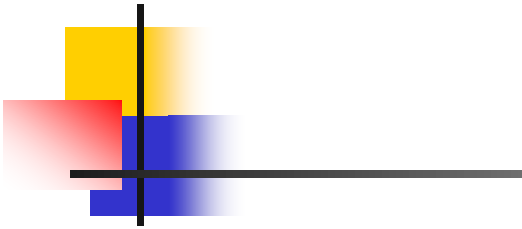


Task 2

~~**WAITING**~~

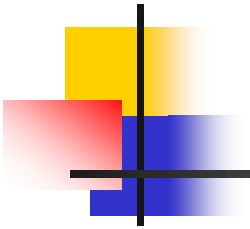


OS_EVENT_TYPE							
OSEVENTCnt							
OSEVENTPtr							
OSEVENTGrp							
7	6	5	4	3	2	1	0
…							
63	62	61	60	59	58	57	56



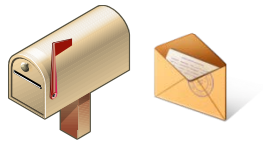
- Data structure

```
typedef struct {
   void   *OSEventPtr;
   INT16U  OSEventCnt;
   INT8U   OSEventType;
   INT8U   OSEventGrp;
   INT8U   OSEventTbl[OS_EVENT_TBL_SIZE];
} OS_EVENT;
```



- OSEventType
  - ECB의 용도를 나타내는 필드
  - OS_EVENT_TYPE_SEM, OS_EVENT_TYPE_MUTEX, OS_EVENT_TYPE_MBOX, OS_EVENT_TYPE_Q
- OSEventCnt
  - 세마포어
    - 세마포어 카운트 저장
  - 상호배제 세마포어
    - PIP 저장
- OSEventPtr
  - 메일박스나 메시지 큐일때만 사용
  - 해당 구조체를 가리키는 포인터
- OSEventGrp, OSEventTbl[]
  - OSRdyTbl[], OSRdyGrp과 비슷한 형태
  - 이벤트의 발생을 기다리는 태스크들의 리스트

EVENT CONTROL BLOCK



Task 1

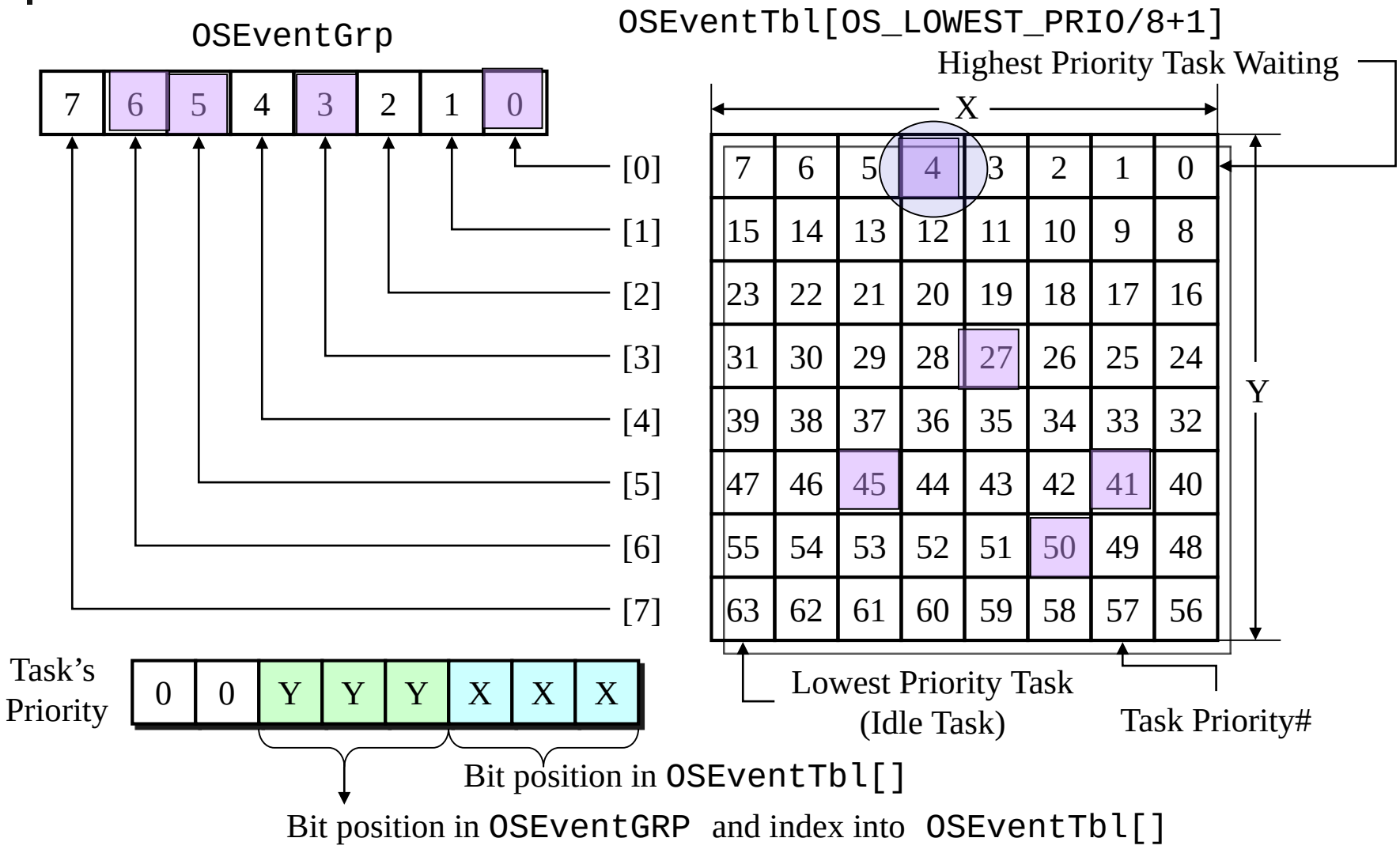
Task 4

Task 27

Task 41

Task 45

Task 50


OSEventGrp
7 6 5 4 3 2 1 0
[0]
[1]
[2]
[3]
[4]
[5]
[6]
[7]
OSEventTbl[OS_LOWEST_PRIO/8+1]
Highest Priority Task Waiting
X
Y
7 6 5 4 3 2 1 0
15 14 13 12 11 10 9 8
23 22 21 20 19 18 17 16
31 30 29 28 27 26 25 24
39 38 37 36 35 34 33 32
47 46 45 44 43 42 41 40
55 54 53 52 51 50 49 48
63 62 61 60 59 58 57 56
Lowest Priority Task
(Idle Task)
Task Priority#
Task's
Priority
0 0 Y Y Y X X X
Bit position in OSEventTbl[]
Bit position in OSEventGRP and index into OSEventTbl[]

Insert a task to event wait list

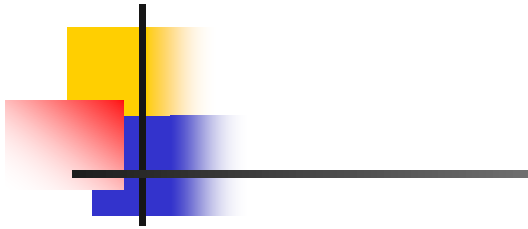
```
pevent->OSEventGrp                  |= OSMapTbl[prio >> 3];
pevent->OSEventTbl[prio >> 3]       |= OSMapTbl[prio & 0x07];
```

Remove a task from event wait list

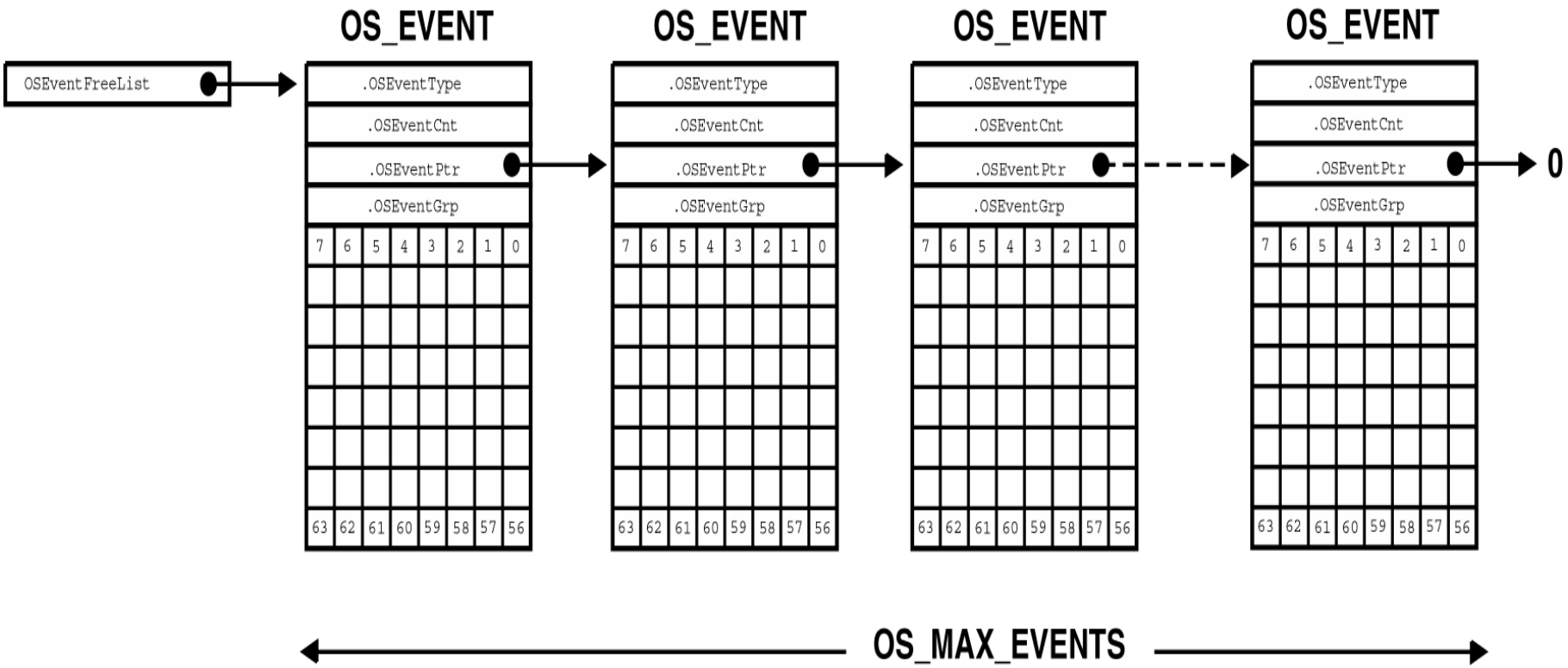
```
if ((pevent->OSEventTbl[prio >> 3] &= ~OSMapTbl[prio & 0x07]) == 0) {
    pevent->OSEventGrp &= ~OSMapTbl[prio >> 3];
}
```

Finding the highest priority task from event wait list

```
y    = OSUnMapTbl[pevent->OSEventGrp];
x    = OSUnMapTbl[pevent->OSEventTbl[y]];
prio = (y << 3) + x;
```

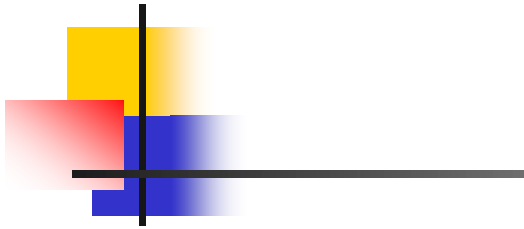


- Free event control block list
  - 할당되는 ECB의 개수는 응용 프로그램에서 요구하는 세마포어, 메일박스, 메시지 큐에 따라 다름
    - ECB 의 최대 개수는 OS_CFG.H 의 OS_MAX_EVENTS 에서 정의됨
    - OS_INIT이 호출되면 모든 ECB 는 자유 이벤트 제어 블록 리스트에 연결
    - 세마포어나 메일박스 큐가 생성되면 자유 이벤트 제어 블록 리스트에서 삭제되고 초기화됨

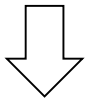

OS_EVENT
OS_EVENT
OS_EVENT
OS_EVENT
OSEventFreeList
.OSEventType
.OSEventCnt
.OSEventPtr
.OSEventGrp
7 6 5 4 3 2 1 0
63 62 61 60 59 58 57 56
0
OS_MAX_EVENTS

Event control block -operations

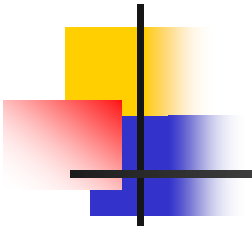
- ECB operations
  - 1. ECB 초기화
    - OS_EventWaitListInit()
  - 2. 태스크를 준비 상태로 만들기
    - OS_EventTaskRdy()
  - 3. 태스크를 어떤 이벤트에 대해 wait 상태로 만들기
    - OS_EventWait()
  - 4. 이벤트를 기다리다가 timeout이 발생하여, 태스크를 준비 상태로 만들기
    - OS_EventTO()



OSXXXCreate
OSXXXDel
OSXXXPend
OSXXXPost
OSXXXAccept
OSXXXQuery



OS_EventWaitListInit()
OS_EventTaskRdy()
OS_EventWait()
OSEventTO()



- ECB 제어 블록 관련 기능
  - OSEventWaitListInit(OS_EVENT *pevent)
    - 세마포어, 메일박스, 메시지 큐 생성 시에 호출되는 함수
    - 단지 ECB를 기다리는 태스크의 리스트가 아직은 없다는 것을 표시하는 것임
  - OSEventTaskRdy()
    - ECB가 시그널을 받아서, ECB를 기다리던 태스크중 가장 우선 순위가 높은 태스크를 실행 가능 상태로 바꿀 때
  - OSEventTaskWait()
    - 태스크를 준비 리스트에서 삭제
    - ECB 의 대기 리스트에 태스크 삽입
  - OSEventTO()
    - 타임아웃으로 태스크 준비 상태 만들기
    - OSSemPend(), OSMboxPend(), OSQPend() 에서 호출

```
void OSEventTaskRdy(OS_EVENT *pevent, void *msg, INT8U msk)
{
    y    = OSUnMapTbl[pevent->OSEventGrp];
    bity = OSMapTbl[y];
    x    = OSUnMapTbl[pevent->OSEventTbl[y];
    bitx = OSMapTbl[x];
    prio = (INT8U) ((y>>3) + x);
    if ((pevent->OSEventTbl[y] &= ~bitx) == 0){
        pevent->OSEventGrp &= ~bity;
    }
    ptcb                = OSTCBPrioTbl[prio];
    ptcb->OSTCBDly      = 0;
    ptcb->OSTCBEventPtr = (OS_EVENT *) 0;
    ptcb->OSTCBStat     &= ~msk;
    if (ptcb->OSTCBStat == OS_STAT_RDY) {
        OSRdyGrp        |= bity;
        OSRdyGrp        |= bitx;
    }
}
```

우선순위가 높은 태스크 찾기

ECB 대기 리스트에서 삭제

OS_STAT_SEM, OS_STAT_MUTEX
OS_STAT_MBOX, OS_STAT_Q

준비 리스트 삽입

```
void OSEventTaskWait(OS_EVENT *pevent)
{
  OSTCBCur->OSTCBEventPtr = pevent;
  if((OSRdyTbl[OSTCBCur->OSTCBY] &= ~OSTCBCur->OSTCBBitX) == 0) {
    OSRdyGrp &= ~OSTCBCur->OSTCBBitY;
  }
  pevent->OSEventTbl[OSTCBCur->OSTCBY] |= OSTCBCur->OSTCBBitX;
  pevent->OSEventGrp                   |= OSTCBCur->OSTCBBitY;
}
```

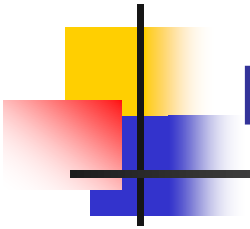
준비 리스트에서 삭제

ECB 대기 리스트에 삽입

```
void OSEventTO (OS_EVENT *pevent)
{
  if((pevent->OSEventTbl[OSTCBCur->OSTCBY] &= ~OSTCBCur->OSTCBBitX)==0) {
    pevent->OSEventGrp &= ~OSTCBCur->OSTCBBitY;
  }
  OSTCBCur->OSTCBStat = OS_STAT_RDY;
  OSTCBCur->OSTCBEventPtr = (OS_EVENT *) 0;
}
```

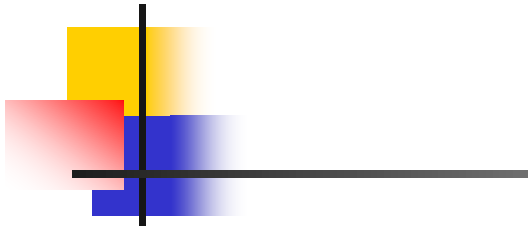
ECB 대기 리스트에서 삭제

해당 **TCB**가 **event** 를 가리키도 않도록 세팅

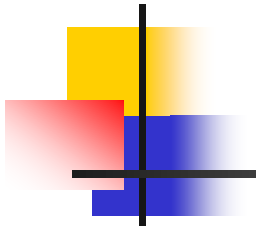


Mailbox

- mailbox 생성
  - OS_EVENT *OSMboxCreate (void *msg)
    - msg: 메시지에 대한 포인터
    - pevent->OSEventPtr = msg;
- mailbox 삭제
  - OS_EVENT *OSMboxDel (OS_EVENT *pevent, INT8U opt, INT8U *err)
  - Mailbox를 삭제하려면 그 Mailbox를 액세스할 수 있는 모든 Task를 먼저 삭제해야 함



- mailbox 에서 메시지 기다리기
  - void *OSMboxPend (OS_EVENT *pevent, INT16U timeout, INT8U *err)
    - 1> .OSEventPtr이 NULL 이 아닌 포인터값을 가지고 있을 때
      - OSMboxPend()가 호출되면, .OSEventPtr값을 msg에 저장하고, 메일박스는 비운다
    - 2> .OSEventPtr에는 NULL pointer값을 저장
    - 3> 메시지가 메일박스에 들어왔을 때, 그리고 OSMboxPend()를 호출한 이 태스크가 다시 HPT가 되었을 때 OSSched()는 이 자리로 복귀하며, message는 호출한 태스크에 넘겨짐



- mailbox 에 메시지 보내기
  - INT8U OSMboxPost (OS_EVENT *pevent, void *msg)
    - 메시지 저장
- 기다리지 않고 mailbox 에서 메시지 읽기
  - void *OSMboxAccept (OS_EVENT *pevent)
- mailbox 대한 정보 얻기
  - INT8U OSMboxQuery (OS_EVENT *pevent, OS_MBOX_DATA *pdata)

```
typedef struct {
    void    *OSMsg;
    INT8U   OSEventTbl[OS_EVENT_TBL_SIZE];
     INT8U   OSEventGrp;
} OS_MBOX_DATA;
```

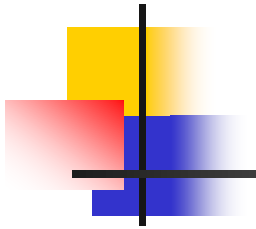
```
void *OSMboxPend (OS_EVENT *pevent, INT16U timeout, INT8U *err)
{
   void *msg;

   if (OSIntNesting > 0) { /* See if called from ISR ... */
      *err = OS_ERR_PEND_ISR; /* ... can't PEND from an ISR */
      return ((void *)0);
   }
#if OS_ARG_CHK_EN > 0
   if (pevent == (OS_EVENT *)0) { /* Validate 'pevent' */
      *err = OS_ERR_PEVENT_NULL;
      return ((void *)0);
   }
   if (pevent->OSEventType != OS_EVENT_TYPE_MBOX) { /* Validate event block type*/
      *err = OS_ERR_EVENT_TYPE;
      return ((void *)0);
   }
#endif
   OS_ENTER_CRITICAL();
   msg = pevent->OSEventPtr;
   if (msg != (void *)0) {       /* See if there is already a message */
      pevent->OSEventPtr = (void *)0; /* Clear the mailbox */
```

0 : wait forever

메시지가 있을 경우

```
        OS_EXIT_CRITICAL();
        *err = OS_NO_ERR;
        return (msg);                /* Return the message received (or NULL) */
    }
    OSTCBCur->OSTCBStat |= OS_STAT_MBOX; /* Message not available, task will pend */
    OSTCBCur->OSTCBDly = timeout; /* Load timeout in TCB */
    OS_EventTaskWait(pevent);     /* Suspend task until event or timeout occurs */
    OS_EXIT_CRITICAL();
    OS_Sched();                   /* Find next highest priority task ready to run */
    OS_ENTER_CRITICAL();
    msg = OSTCBCur->OSTCBMsg;
    if (msg != (void *)0) {       /* See if we were given the message */
        OSTCBCur->OSTCBMsg = (void *)0; /* Yes, clear message received */
        OSTCBCur->OSTCBStat = OS_STAT_RDY;
        OSTCBCur->OSTCBEventPtr = (OS_EVENT *)0; /* No longer waiting for event */
        OS_EXIT_CRITICAL();
        *err = OS_NO_ERR;
        return (msg);             /* Return the message received */
    }
    OS_EXIT_CRITICAL();
    *err = OS_TIMEOUT;            /* Indicate that a timeout occurred */
    return ((void *)0);           /* Return a NULL message */
}
```

대시간가 없을 경우 (2)



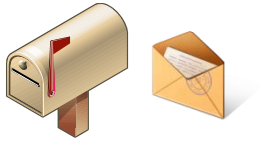
```
INT8U OSMboxPost (OS_EVENT *pevent, void *msg)
{
#if OS_ARG_CHK_EN > 0
   if (pevent == (OS_EVENT *)0) { /* Validate 'pevent' */
      return (OS_ERR_PEVENT_NULL);
   }
   if (msg == (void *)0) {   /* Make sure we are not posting a NULL pointer */
      return (OS_ERR_POST_NULL_PTR);
   }
   if (pevent->OSEventType != OS_EVENT_TYPE_MBOX) { /* Validate event block type */
      return (OS_ERR_EVENT_TYPE);
   }
#endif

   OS_ENTER_CRITICAL();
   if (pevent->OSEventGrp != 0x00) { /* See if any task pending on mailbox */
      OS_EventTaskRdy(pevent, msg, OS_STAT_MBOX);
                              /* Ready highest priority task waiting on event */
      OS_EXIT_CRITICAL();
      OS_Sched();             /* Find highest priority task ready to run */
      return (OS_NO_ERR);
   }
```

(1)

```
    if (pevent->OSEventPtr != (void *)0) {
                                /* Make sure mailbox doesn't already have a msg */
        OS_EXIT_CRITICAL();
        return (OS_MBOX_FULL);
    }
    pevent->OSEventPtr = msg; /* Place message in mailbox */
    OS_EXIT_CRITICAL();
    return (OS_NO_ERR);
}
```

EVENT CONTROL BLOCK

Task 1



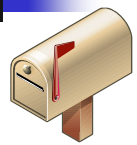
Task 2

OSMboxPost

<1>

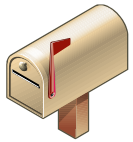
OSMboxPend ~~**WAITING**~~

<2>



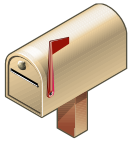
```
TxMbox  = OSMboxCreate((void *)0);
```

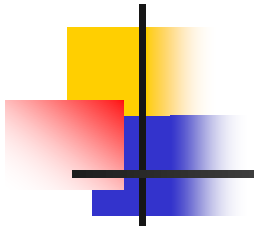
```
char  *rxmsg;
INT8U  err;
```



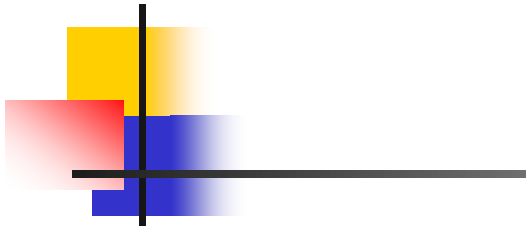
```
rxmsg = (char *)OSMboxPend(TxMbox, 0, &err);
```

```
char  txmsg;
OSMboxPost(TxMbox, (void *)&txmsg);
```



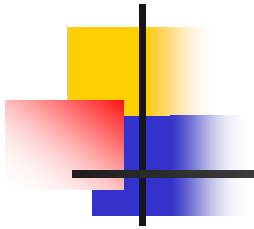


- OSMboxPostOpt()
  - Mailbox에 대기 중인 모든 Task에게 메시지를 Broadcast할 수 있는 기능 추가
    - 전달인자
      - Pevent: 해당 Mailbox의 ECB에 대한 포인터
      - Timeout: 옵션 타임아웃 값(Clock Tick 단위)



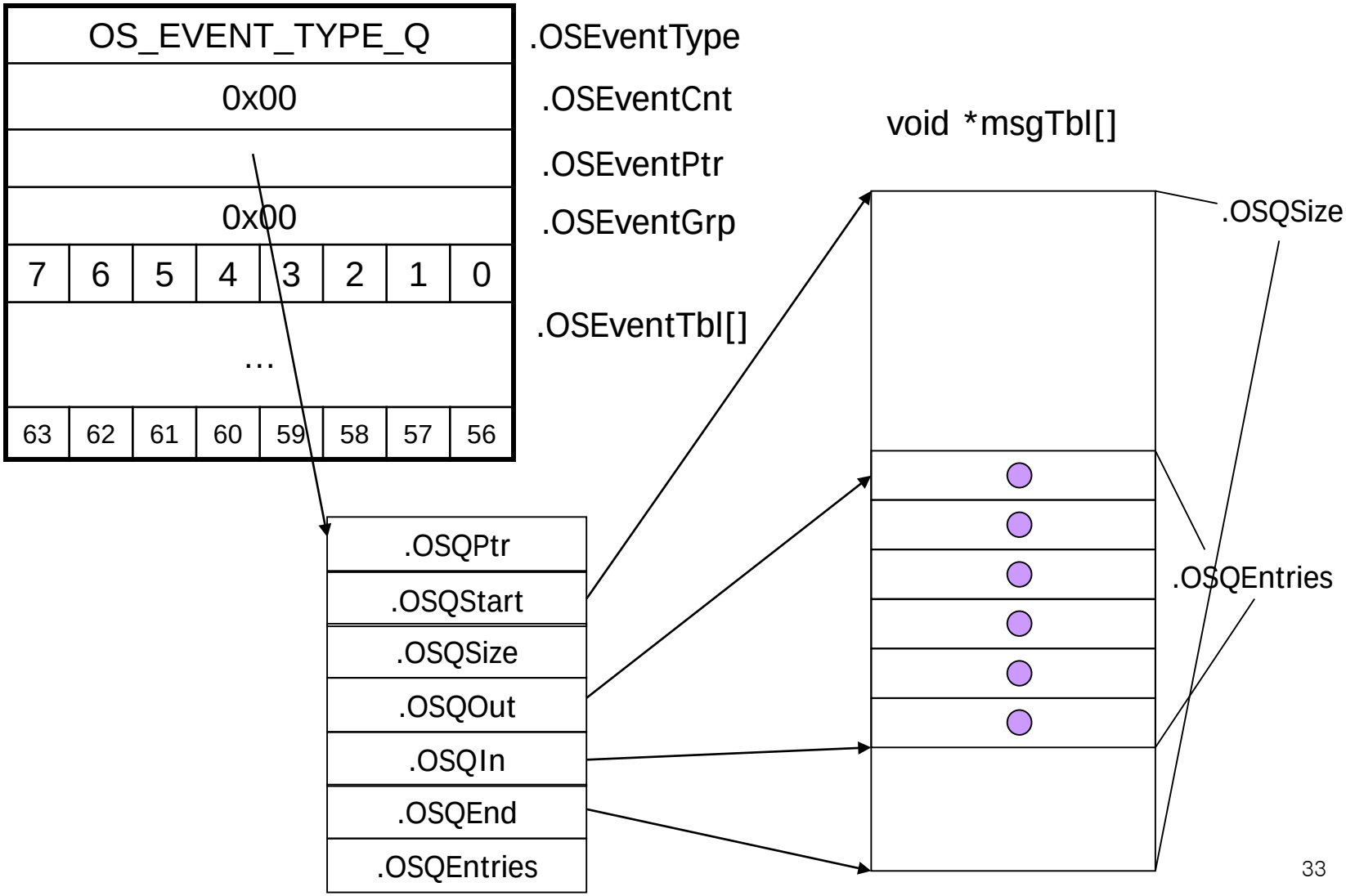
```
INT8U OSMboxPostOpt (OS_EVENT *pevent , void *msg, INT8U opt)
{
#if OS_ARG_CHK_EN > 0
   if (pevent == (OS_EVENT *)0) { /* Validate 'pevent ' */
      return (OS_ERR_PEVENT_NULL);
   }
   if (msg == (void *)0) { /* Make sure we are not posting a NULL pointer */
      return (OS_ERR_POST_NULL_PTR);
   }
   if (pevent->OSEventType != OS_EVENT_TYPE_MBOX) { /* Validate event block type */
      return (OS_ERR_EVENT_TYPE);
   }
#endif
   OS_ENTER_CRITICAL();
```

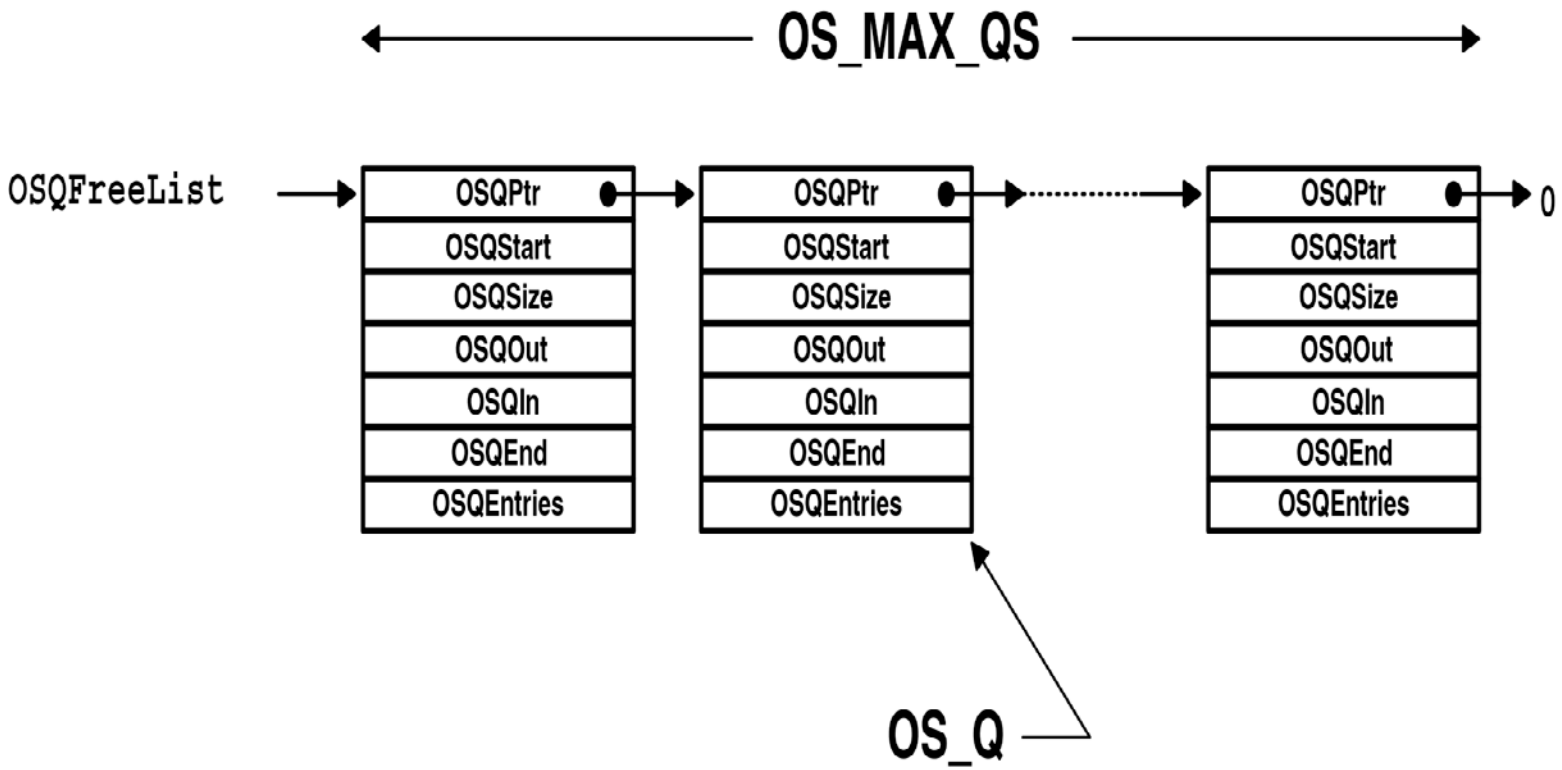
```
   if (pevent->OSEventGrp != 0x00) { /* See if any task pending on mailbox */
      if ((opt & OS_POST_OPT_BROADCAST) != 0x00) {
                        /* Do we need to post msg to ALL waiting tasks ? */
         while (pevent ->OSEventGrp != 0x00) {
                              /* Yes, Post to ALL tasks waiting on mailbox */
            OS_EventTaskRdy(pevent, msg, OS_STAT_MBOX);
         }
      } else {
         OS_EventTaskRdy(pevent , msg, OS_STAT_MBOX);
                                       /* No, Post to HPT waiting on mbox */
      }
      OS_EXIT_CRITICAL();
      OS_Sched(); /* Find highest priority task ready to run */
      return (OS_NO_ERR);
   }
   if (pevent->OSEventPtr!= (void *)0) {
                              /* Make sure mailbox doesn't already have a msg */
      OS_EXIT_CRITICAL();
      return (OS_MBOX_FULL);
   }
   pevent->OSEventPtr= msg;   /* Place message in mailbox */
   OS_EXIT_CRITICAL();
   return (OS_NO_ERR);
}
```

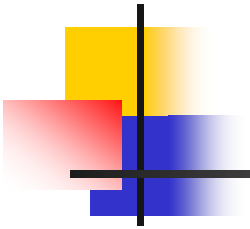


- OSMboxAccept()
  - 호출 Task를 대기상태로 만들지 않고 메시지를 받을 수 있음
  - 전달인자
    - Pevent: 해당 Mailbox의 ECB에 대한 포인터

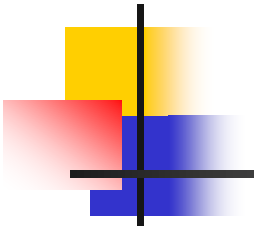
Message queue




OS_MAX_QS
OSQFreeList
OSQPtr
OSQStart
OSQSize
OSQOut
OSQIn
OSQEnd
OSQEntries
OSQPtr
OSQStart
OSQSize
OSQOut
OSQIn
OSQEnd
OSQEntries
OSQPtr
OSQStart
OSQSize
OSQOut
OSQIn
OSQEnd
OSQEntries
0
OS_Q



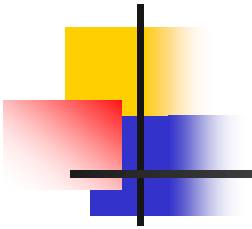
- Message queue 생성
  - OS_EVENT *OSQCreate (void **start, INT16U size)
    - 메시지를 담을 포인터 배열이 미리 할당되어야 함
- Message queue에 메시지 오기를 기다림
  - void *OSQPend (OS_EVENT *pevent, INT16U timeout, INT8U *err)
    - 메시지가 큐에 도착하기를 기다리는 함수
      - 만약 큐 속에 저장되어 있던 메시지가 없다면, 새로운 메시지가 도착하거나, timeout 시간이 지날 때까지 태스크를 sleep 시키고는 scheduler(OSSched())를 호출한다.
      - 다시 이 OSQPend()가 HPT가 되었을 때, 새로 들어온 메시지가 있다면 메시지를 꺼낸다.



- Message queue에 배달된 모든 메시지 삭제
  - INT8U OSQFlush (OS_EVENT *pevent)
- Broadcasting
  - INT8U OSQPostOpt (OS_EVENT *pevent, void *msg, INT8U opt)

OS_POST_OPT_BROADCAST

- Non-blocking message queue
  - void *OSQAccept (OS_EVENT *pevent)



```
void *OSMboxAccept (OS_EVENT *pevent)
{
   void * msg;

   OS_ENTER_CRITICAL();
   if (pevent->OSEventType != OS_EVENT_TYPE_MBOX) {
      OS_EXIT_CRITICAL();
      return ((void *)0);
   }
   msg = pevent->OSEventPtr;
   if (msg != (void *)0) {
      pevent->OSEventPtr = (void *)0;
   }
   OS_EXIT_CRITICAL();
   return (msg);
}
```

```
#define       MSG_QUEUE_SIZE     20
void          *MsgQueueTbl[20];                /* Storage for messages  */
MsgQueue = OSQCreate(&MsgQueueTbl[0], MSG_QUEUE_SIZE);
```

```
char  *msg;
INT8U  err;
msg = (char *)OSQPend(MsgQueue, 0, &err);
```

```
char  msg[20];
strcpy(&msg[0], "Task 3");
 OSQPost(MsgQueue, (void *)&msg[0]);
```