FreeRTOS Timers

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Textbook Reference

- Mastering the FreeRTOS Real Time Kernel by Richard Barry

  - Chapter 5: Software Timer Management

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Topics

- 5.1 Intro and Scope
- 5.2 Software Timer Callback Functions
- 5.3 Attributes and States of a Software Timer
- 5.4 The Context of a Software Timer
- 5.5 Creating and Starting a Software Timer
- 5.6 The Timer ID
- 5.7 Changing the Period of a Timer
- 5.8 Resetting a Software Timer

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5.1 Intro and Scope

- Two options for using software timers
  - Option 1.
    - Schedule the execution of a function at a **set time** in the future
  - Option 2.
    - Schedule the execution of a function **periodically** with a fixed frequency

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Software Timers Implemented by FreeRTOS

- Software Timers are implemented by FreeRTOS
  - They are optional
    - configSOFTWARE_TIMERS must be set to 1 in FreeRTOSConfig.h
  - They do NOT require hardware support
    - They are NOT related to hardware timers
      - They do NOT use any processing time unless the callback is executing

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What you will learn

- Characteristics of software timer compared to task
- The RTOS daemon task
- The timer command queue
- The difference between a one shot timer and a periodic
- How to create, start, reset, and change the period of a timer

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5.2 Software Timer Callback Functions

- Software timer implemented a C function with this prototype
    - void MyTimerCallback(TimerHandle_t xTimer)
- Timer functions execute from start to finish
    - Must be kept short, and never enter Blocked state
- Note: Software timer functions execute in the context of a daemon task created by the FreeRTOS Scheduler

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To repeat: Software Timers cannot call blocking APIs

- OK to call from Software Timer
  - xQueueReceive() with xTicksToWait set to 0 (no waiting)
- Not OK to call
  - vTaskDelay()

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5.3 Attributes and States of a Software Timer

- Period of a software timer
  - The time between the software timer being started and the timers callback function executing
- One-Shot Timer
  - Once started, only calls callback function once
- Auto-Reload Timer
  - Auto starts after callback function called

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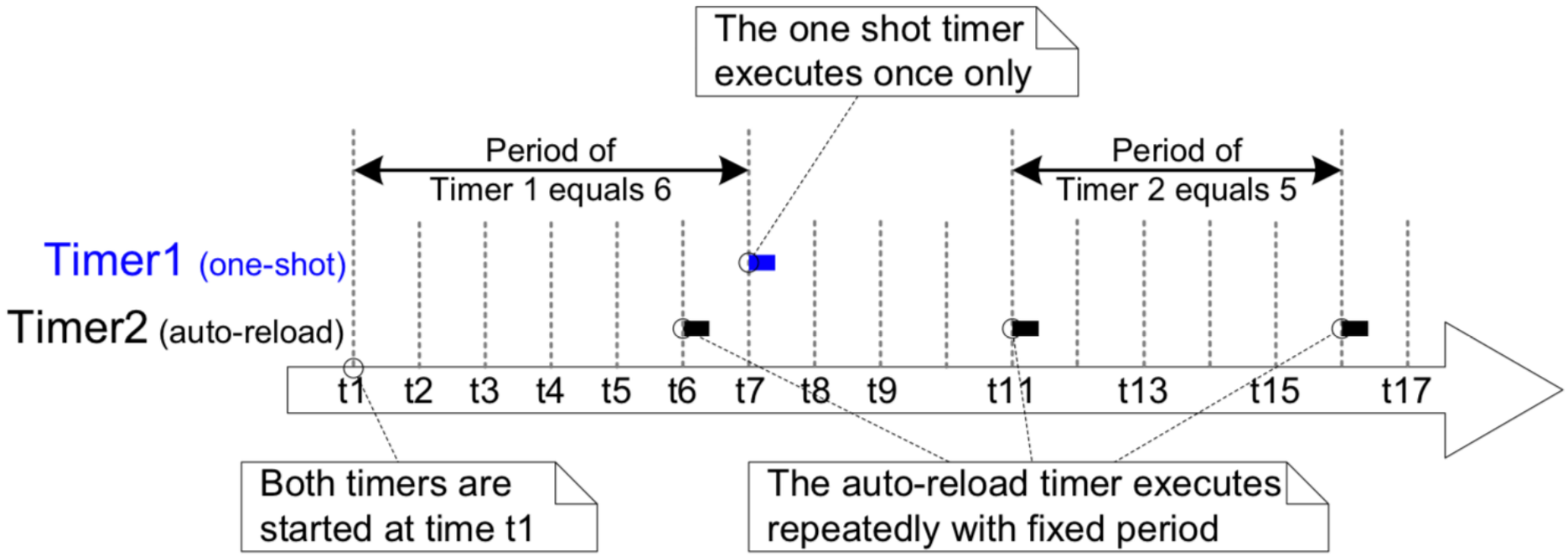
Block Diagram



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Software Timer State

- Software Timers have two states
  - Dormant
    - Timer exists but callback function not running
- Running
  - Callback function is executing

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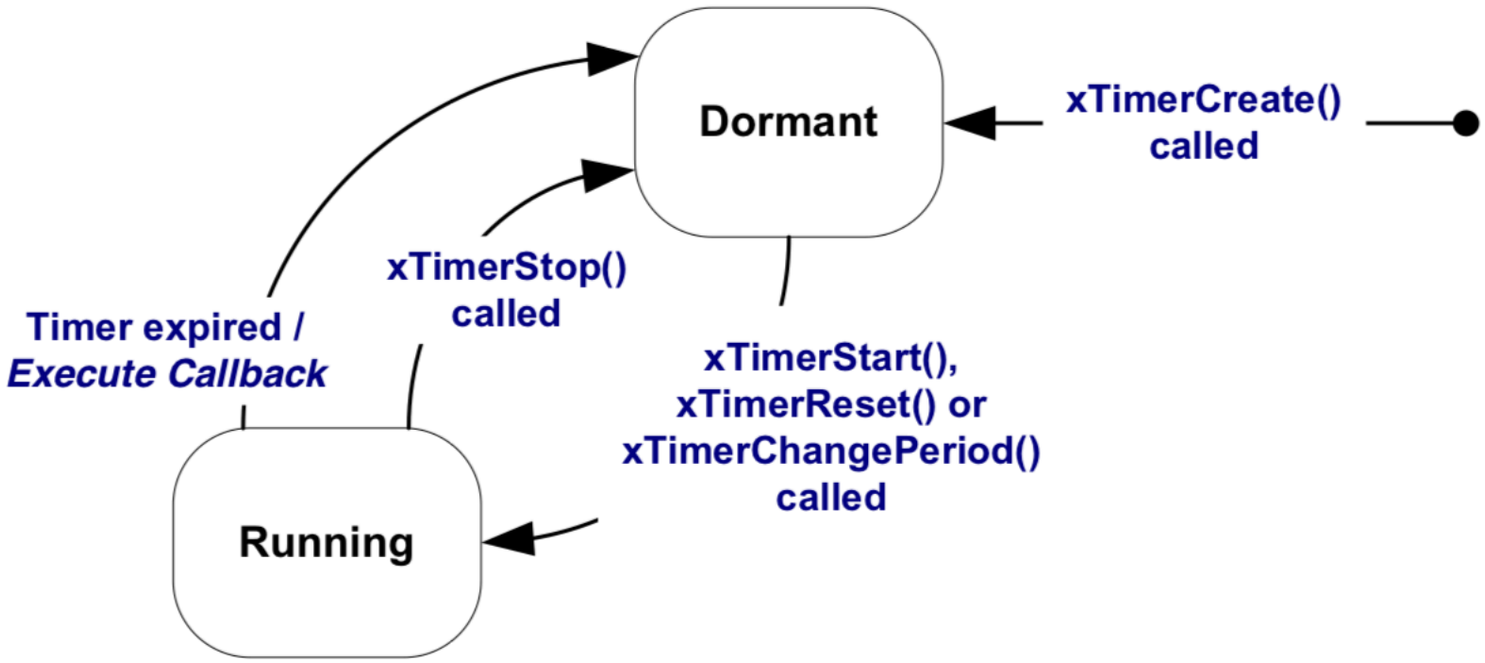
Block Diagram
One-Shot Timer



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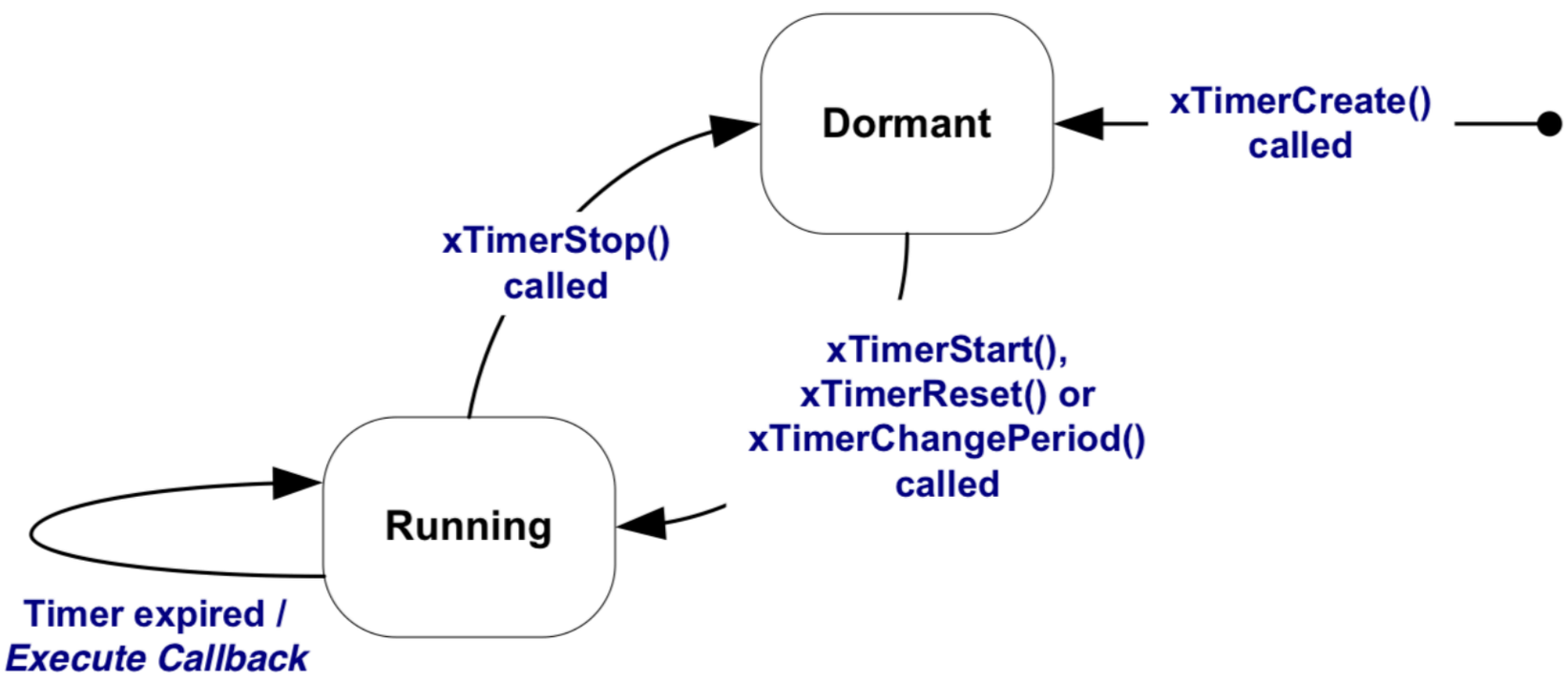
Block Diagram
Auto Reload Timer



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5.4 The Context of a Software Timer

- All software timers execute in the context of the FreeRTOS daemon task
  - Also called the “timer service” task
- FreeRTOS daemon task created automatically when the scheduler starts
- Configuration of FreeRTOS daemon task
  - configTIMER_TASK_PRIORITY
  - configTIMER_TASK_STACK_DEPTH

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Timer Command Queue

- Software Timer API functions send commands from the calling task to the daemon task on a queue
  - The “timer command queue”
    - Standard FreeRTOS queue created when Scheduler starts
      - configTIMER_QUEUE_LENGTH
- Example commands
  - Start a Timer
  - Stop a Timer
  - Reset a Timer

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Block Diagram

Application Code

```
/* A function implemented in
an application task. */
void vAFunction( void )
{
    /* Write function code
    here. */
    ....
    /* At some point the
    xTimerReset() API
    function is called.
    The implementation of
    xTimerReset() writes to
    the timer command queue.
    */
    xTimerReset();

    /* Write the rest of the
    function code here. */
}
```

FreeRTOS (kernel) Code

```
/* A pseudo representation
of the FreeRTOS daemon task.
This is not the real
code! */
void prvTimerTask( ... )
{
    for( ;; )
    {
        /* Wait for a
        command. */
        xQueueReceive();

        /* Process the
        command. */
    }
}
```

The API function writes to the timer command queue

Timer command queue

The RTOS daemon task reads from the timer command queue

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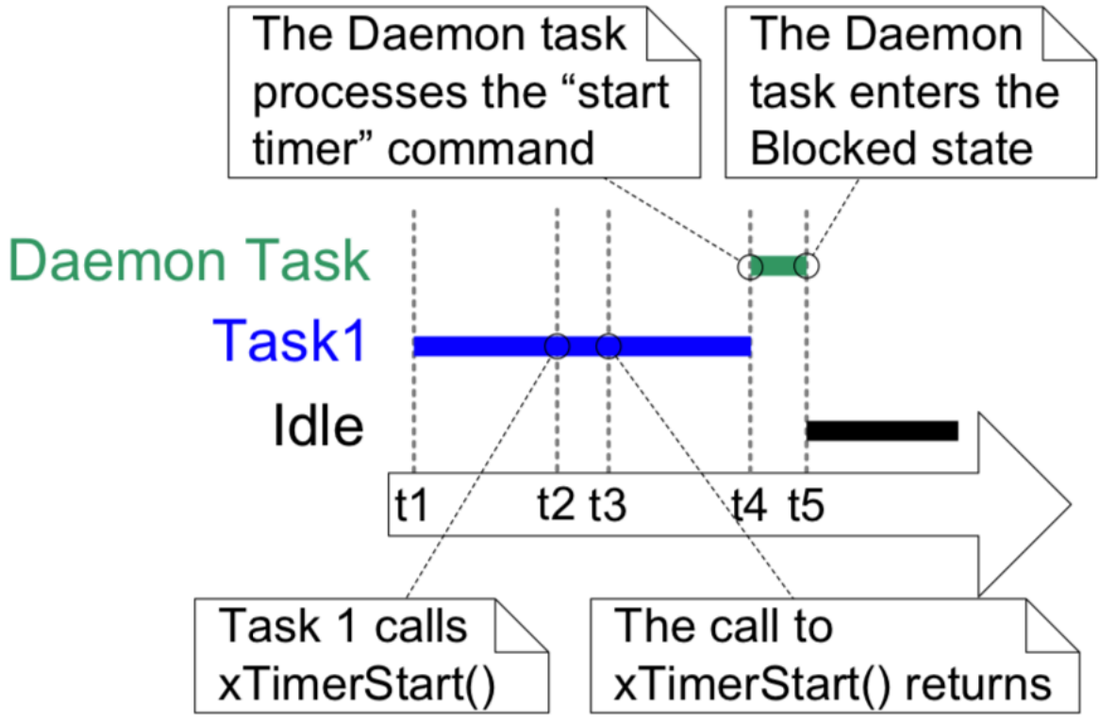
Daemon Task Scheduling Example 1 - Task 1 has higher priority than Daemon Task

- Like any other FreeRTOS task, the daemon task only runs when it is the highest priority



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5.5 Creating and Starting a Software Timer

- To create a software timer
  - xTimerCreate()
  - xTimerCreateStatic()

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xTimerCreate()

- TimerHandle_t
  xTimerCreate(
    const char *const pcTimerName,
    TickType_t xTimerPeriodInTicks,
    UBaseType_t uxAutoReload,
    void *pvTimerID,
    TimerCallbackFunction_t pxCallbackFunction)

- Notes
  - Use pdMS_TO_TICKS() to set xTimerPeriodInTicks
  - If uxAutoReload = 0, then one-shot, If uxAutoReload = 1, then auto-reload
  - pvTimerID is a pointer returned and can be used as needed by app developer - useful when same callback is used with more than one timer
  - Returns non-NULL if timer created

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xTimerStart()

- BaseType_t
  xTimerStart(
  TimerHandle_t xTimer,
  TickType_t xTicksToWait)

- Notes
  - xTicksToWait is how long to wait if command queue is full - use value of 0 if you want to return immediately if full
  - If INCLUDE_vTaskSuspend is 1, then setting xTicksToWait to portMAX_DELAY will result in calling task staying in blocked state indefinitely until room available in queue
  - Returns pdPASS or pdFALSE
  - Do not call this from an ISR
    - Use xTimerStartFromISR()

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Code Demo - Part 1

- #define mainONE_SHOT_TIMER_PERIOD pdMS_TO_TICKS(3333)
- #define mainAUTO_RELOAD_TIMER_PERIOD pdMS_TO_TICKS(500)
- int main(void) {
    TimerHandle_t xOneShotTimer;
    TimerHandle_t xAutoReloadTimer;
    BaseType_t xTimerOneShotStarted;
    BaseType_t xTimerAutoReloadStarted;

    xOneShotTimer = xTimerCreate(“OneShot”, mainONE_SHOT_PERIOD, pdFALSE, 0, prvOneShotTimerCallback);
   xAutoReloadTimer = xTimerCreate(“AutoReload”, MainAUTO_RELOAD_TIMER_PERIOD, pdTRUE, 0, prvAutoReloadTimerCallback);

If ((xOneShotTimer != NULL) && (xAutoReloadTimer != NULL)) {
    xTimerOneShotStarted = xTimerStart(xOneShotTimer, 0);
    xTimerAutoReloadStarted = xTimerStart(xAutoReloadTimer, 0);
    if ((xTimerOneShotStarted) && (xTimerAutoReloadStarted)) {
        vTaskStartScheduler();
    }
}

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Code Demo - Part 2

- static void **prvOneShotTimerCallback**(TimerHandle_t xTimer)
  {
    TickType_t xTimeNow;
    xTimeNow = uxTaskGetTickCount();

    vPrintStringAndNumber("One-shot callback\r\n", xTimeNow);
    ulCallCount++;
  }

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Code Demo - Part 3

- Static void prvAutoReloadTimerCallback(TimerHandle_t xTimer) {
    TickType_t xTimeNow;
    vPrintStringAndNumber(“Auto-reload timer”, xTimeNow);
    ulCallCount++;
}

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5.6 The Timer ID

- Each software timer has an ID
  - ID can be used by app writer for any purpose
    - Stored as a void pointer (void *) so that it can be any value
- Timer ID related functions
  - vTimerSetTimerID()
  - pvTimerGetTimerID()

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Code Demo

```
• static void prvTimerCallback(TimerHandle_t *xTimer) {
    TickType_t xTimeNow;
    uint32_t ulExecutionCount;
    ulExecutionCount = (uint32_t) pvTimerGetTimerID(xTimer);
    ulExecutionCount++;
    vTimerSetTimerID(xTimer, (void *)ulExecutionCount);
    xTimeNow = xTaskGetTickCount();

    if (xTimer == xOneShotTimer) {
        vPrintStringAndNumber(“One shot executing”, xTimeNow);
    }
    else {
        vPrintStringAndNumber(“Auto-reload executing”, xTimeNow);
        if (ulExectionCount == 5) {
            xTimerStop(xTimer, 0);
        }
    }
}
```


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5.7 Changing the Period of a Timer

- You have the option to change the period of the timer
- Example:
  - Use one period of the timer to flash LED at normal period
  - Use another period of the timer to flash LED at faster period to alert to errors

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xTimerChangePeriod()

- BaseType_t
  xTimerChangePeriod(
  TimerHandle_t xTimer,
  TickType_t xNewTimerPeriodInTicks,
  TickType_t xTicksToWait)

- Notes
  - Set xNewImterPeriodInTicks with pdMS_TO_TICKS() macro
  - Set xTicksToWait to 0 if you do not want to wait if Timer command queue is full
    - If INCLUDE_vTaskSuspend is set to 1, then portMAX_DELAY will result in task being blocked until Queue has space
  - Returns pdPASS or pdFALSE
  - Never call xTimerChangePeriod() in an ISR - call xTimerChangePeriodFromISR() instead

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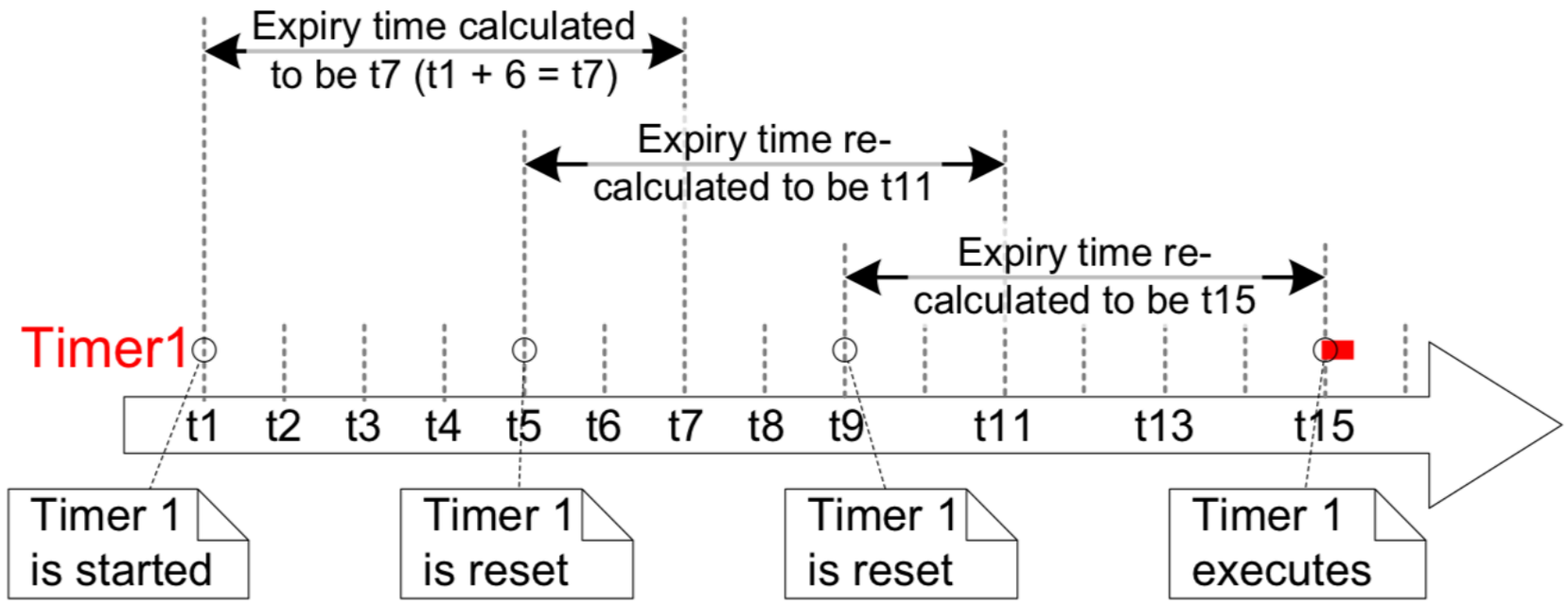
5.8 Resetting a Software Timer

- Resetting a software timer means to restart the timer



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xTimerReset()

- BaseType_t
  xTimerReset(
      TimerHandle_t xTimer,
      TickType_t xTicksToWait)

- Notes

  - Set xTicksToWait to 0 if you do not want to wait if Timer command queue is full

    - If INCLUDE_vTaskSuspend is set to 1, then portMAX_DELAY will result in task being blocked until Queue has space

  - Returns pdPASS or pdFALSE

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Summary

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