|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Lesson 4 OK04  The OK04 lesson builds on OK03 by teaching how to use the timer to flash the 'OK' or 'ACT' LED at precise intervals. It is assumed you have the code for the [Lesson 3: OK03](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok03.html) operating system as a basis.   |  | | --- | | **Contents**   * [1 A New Device](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok04.html#newdevice) * [2 Implementation](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok04.html#implementation) * [3 Another Blinking Light](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok04.html#abl) |   1 A New Device  The timer is the only way the Pi can keep time. Most computers have a battery powered clock to keep time when off.  So far, we've only looked at one piece of hardware on the Raspberry Pi, namely the GPIO Controller. I've simply told you what to do, and it happened. Now we're going to look at the timer, and I'm going to lead you through understanding how it works.  Just like the GPIO Controller, the timer has an address. In this case, the timer is based at 2000300016. Reading the manual, we find the following table:   | Table 1.1 GPIO Controller Registers | | | | | | --- | --- | --- | --- | --- | | **Address** | **Size / Bytes** | **Name** | **Description** | **Read or Write** | | 20003000 | 4 | Control / Status | Register used to control and clear timer channel comparator matches. | RW | | 20003004 | 8 | Counter | A counter that increments at 1MHz. | R | | 2000300C | 4 | Compare 0 | 0th Comparison register. | RW | | 20003010 | 4 | Compare 1 | 1st Comparison register. | RW | | 20003014 | 4 | Compare 2 | 2nd Comparison register. | RW | | 20003018 | 4 | Compare 3 | 3rd Comparison register. | RW |   Flowchart of the system timer's operation  This table tells us a lot, but the descriptions in the manual of the various fields tell us the most. The manual explains that the timer fundamentally just increments the value in Counter by 1 every 1 micro second. Each time it does so, it compares the lowest 32 bits (4 bytes) of the counter's value with the 4 comparison registers, and if it matches any of them, it updates Control / Status to reflect which ones matched.  For more information about bits, bytes, bit fields, and data sizes expand the box below.  Bits explained  A bit is a name for a single binary digit. As you may recall, a single binary digit is either a 1 or a 0.  A byte is the name we give for a collection of 8 bits. Since each bit can be one of two values, there are 28 = 256 different possible values for a byte. We normally interpret a byte as a binary number between 0 and 255 inclusive.  Diagram of GPIO function select controller register 0.  A bit field is another way of interpreting binary. Rather than interpreting it as a number, binary can be interpreted as many different things. A bit field treats binary as a series of switches which are either on (1) or off (0). If we have a meaning for each of these little switches, we can use them to control things. We have actually already met bitfields with the GPIO controller, with the setting a pin on or off. The bit that was a 1 was the GPIO pin to actually turn on or off. Sometimes we need more options than just on or off, so we group several of the switches together, such as with the GPIO controller function settings (pictured), in which every group of 3 bits controls one GPIO pin function.  Our goal is to implement a function that we can call with an amount of time as an input that will wait for that amount of time and then return. Think for a moment about how we could do this, given what we have.  I see there being two options:   1. Read a value from the counter, and then keep branching back into the same code until the counter is the amount of time to wait more than it was. 2. Read a value from the counter, add the amount of time to wait, store this in one of the comparison registers and then keep branching back into the same code until the Control / Status register updates.   Issues like these are called concurrency problems, and can be almost impossible to fix.  Both of these strategies would work fine, but in this tutorial we will only implement the first. The reason is because the comparison registers are more likely to go wrong, as during the time it takes to add the wait time and store it in the comparison register, the counter may have increased, and so it would not match. This could lead to very long unintentional delays if a 1 micro second wait is requested (or worse, a 0 microsecond wait).  2 Implementation  Large Operating Systems normally use the Wait function as an opportunity to perform background tasks.  I will largely leave the challenge of creating the ideal wait method to you. I suggest you put all code related to the timer in a file called 'systemTimer.s' (for hopefully obvious reasons). The complicated part about this method, is that the counter is an 8 byte value, but each register only holds 4 bytes. Thus, the counter value will span two registers.  The following code blocks are examples.  ldrd r0,r1,[r2,#4]  **ldrd regLow,regHigh,[src,#val]** loads 8 bytes from the address given by the number in **src** plus **val** into **regLow** and **regHigh** .  An instruction you may find useful is the **ldrd** instruction above. It loads 8 bytes of memory across 2 registers. In this case, the 8 bytes of memory starting at the address in **r2** would be copied into **r0** and **r1**. What is slightly complicated about this arrangement is that **r1** actually holds the highest 4 bytes. In other words, if the counter had a value of 999,999,999,99910 = 11101000110101001010010100001111111111112, **r1** would contain 111010002 and **r0** would contain 110101001010010100001111111111112.  The most sensible way to implement this would be to compute the difference between the current counter value and the one from when the method started, and then to compare this with the requested amount of time to wait. Conveniently, unless you wish to support wait times that were 8 bytes, the value in **r1** in the example above could be discarded, and only the low 4 bytes of the counter need be used.  When waiting you should always be sure to use higher comparisons not equality comparisons, as if you try to wait for the gap between the time the method started and the time it ends to be exactly the amount requested, you could miss the value, and wait forever.  If you cannot figure out how to code the wait function, expand the box below for a guide.  Wait function implementation  Borrowing the idea from the GPIO controller, the first function we should write should be to get the address of this system timer. An example of this is shown below:  .globl GetSystemTimerBase GetSystemTimerBase:  ldr r0,=0x20003000 mov pc,lr  Another function that will prove useful would be one that returns the current counter value in registers **r0** and **r1**:  .globl GetTimeStamp GetTimeStamp: push {lr} bl GetSystemTimerBase ldrd r0,r1,[r0,#4] pop {pc}  This function simply uses the GetSystemTimerBase function and loads in the counter value using **ldrd** like we have just learned.  Now we actually want to code our wait method. First of all, we need to know the counter value when the method started, which we can now get using GetTimeStamp.  delay .req r2 mov delay,r0 push {lr} bl GetTimeStamp start .req r3 mov start,r0  This code copies our method's input, the amount of time to delay, into **r2**, and then calls GetTimeStamp, which we know will return the current counter value in **r0** and **r1**. It then copies the lower 4 bytes of the counter's value to **r3**.  Next we need to compute the difference between the current counter value and the reading we just took, and then keep doing so until the gap between them is at least the size of **delay**.  loop$:  bl GetTimeStamp elapsed .req r1 sub elapsed,r0,start cmp elapsed,delay .unreq elapsed bls loop$  This code will wait until the requested amount of time has passed. It takes a reading from the counter, subtracts the initial value from this reading and then compares that to the requested delay. If the amount of time that has elapsed is less than the requested delay, it branches back to **loop$**.  .unreq delay .unreq start pop {pc}  This code finishes off the function by returning.  3 Another Blinking Light  Once you have what you believe to be a working wait function, change 'main.s' to use it. Alter everywhere you wait to set the value of r0 to some big number (remember it is in microseconds) and then test it on the Raspberry Pi. If it does not function correctly please see our troubleshooting page.  Once it is working, congratulations you have now mastered another device, and with it, time itself. In the next and final lesson in the OK series, [Lesson 5: OK05](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok05.html) we shall use all we have learned to flash out a pattern on the LED. | 第4课 OK04  OK04课是建立在OK03课程的基础上的。这一课主要讲述如何使用定时器，以精确的时间间隔来闪烁“OK”或者“ACT”LED灯。本课假设你拥有了第3课的代码作为基础。  目录   1. 一个新的设备 2. 实现 3. 另外一种闪烁之法 4. 一个新的设备   计时器（或者定时器）是树莓派仅有的用于保持时间感知的设备。大多数计算机都用于一个电池供电的时钟。一旦掉电该时钟用于保持时刻。之前我们已经了解了一点树莓派的一块硬件设备——GPIO控制器。我也告诉你做什么，和它如何反馈。现在让我们来学习一下计时器吧。  和GPIO控制器一样，计时器也有一个地址。本例子中，计时器的基地址是在20003000（16进制数值）。经过阅读手册，我们发现了下面的表格：  （表格）  （图）  这张表告诉我们很多。而且手册通常会告诉你各个变量域的尽可能多的解释。手册解释了：计时器每增加1，用时1微秒。每一次增加1，它就会把计时器的最末尾的32位（4个字节）和4个比较寄存器的数值进行比较，如果匹配了它们中的其中的一个，它就会更新控制/状态寄存器来反映那个寄存器匹配了。  关于这些位、字节、位域和数据尺寸的更多信息，请阅读下面的解释方块。  位的解释。  我们的目标是实现一个函数，该函数以一段时间数值作为输入，函数会在接收到该数值后进行精确的该时间数值的等待，等到时间段到期后就会返回。好好思考一下我们应该怎么做，并给出你的解决方案。  我认为这里有两个选项：   1. 从计时器中读取一个数值，直到计时器等待的时间到达了它应该等待的时间时，然后跳转回相同的代码处。 2. 从计数器中读取一个数值，添加一段时间去等待，并把该时间值存储在几个比较寄存器里的一个之中，然后直到控制/状态寄存器更新后，跳转回代码的相同位置处。   这些被称为并发性的问题，几乎不太可能修复。  两个策略都可以很好的工作，但是在这一讲里我们只想实现第一种。原因是比较寄存器在获取等待时间并把它存储在比较寄存器中时，计时器中的数值可能已经增加了，这样产生的不匹配很可能让比较寄存器发生错误。如果等待的时间是1微秒的话，将会导致不期望的非常长的延迟（更加糟糕的情况是当需要等待的时间是0微秒时。）。   1. 实现   体量大的操作系统在执行后台任务时通常的做法是使用等待函数。  我会把实现这个等待函数的想法大部分地留给你来实现。我建议你把所有和计时器相关的函数都放置在一个名叫“systemTimer.s”的文件里（目的是见名知意）。这个函数最复杂的部分是计时器持有8字节数值，而寄存器仅仅能保存4个字节的数据。因此，计数器的数值要霸占2个寄存器。  下面的代码就是个例子。  ldrd r0, r1, [r2, #4]  指令ldrd regLow, regHigh, [src, #val]意思是把由src+val的数值作为地址的存储器中存储的数值（8个字节）装载到regLow和regHigh寄存器中。  一个很有用的指令就是刚刚看到的ldrd指令。它会把存储器中8个字节的数值装载到2个寄存器中。在本例中，在存储器地址为寄存器r2中数值的地方连续8个字节的数值将会被拷贝到寄存器r0和r1中去。比较复杂的地方是寄存器r1将保存8个字节的高地址的4个字节。如果计时器里保存了十进制数值999,999,999,999（其二进制表示为：1110100011010100101001010000111111111111）,寄存器r1将保存二进制数值11101000，并且寄存器r0将保存二进制数值。  最合理的实现方法是：该方法计算当前计时器 |