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| Lesson 2 OK02  The OK02 lesson builds on OK01, by causing the 'OK' or 'ACT' LED to turn on and off repeatedly. It is assumed you have the code for the [Lesson 1: OK01](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok01.html) operating system as a basis.   |  | | --- | | **Contents**   * [1 Waiting](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok02.html#waiting) * [2 The All Together](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok02.html#together) |   1 Waiting  Waiting is a surprisingly useful part of Operating System development. Often Operating Systems find themselves with nothing to do, and must delay. In this example, we wish to do so in order to allow the LED flashing off and on to be visible. If you just turned it off and on, it would not be visible, as the computer would be able to turn it off and on many thousands of times per second. In later lessons we will look at accurate waiting, but for now it is sufficient to simply waste time.  mov r2,#0x3F0000 wait1$: sub r2,#1 cmp r2,#0 bne wait1$  **sub reg,#val** subtracts the number **val** from the value in **reg**.  **cmp reg,#val** compares the value in **reg** with the number **val**.  Suffix **ne** causes the command to be executed only if the last comparison determined that the numbers were not equal.  The code above is a generic piece of code that creates a delay, which thanks to every Raspberry Pi being basically the same, is roughly the same time. How it does this is using a **mov** command to put the value 3F000016 into **r2**, and then subtracting 1 from this value until it is 0. The new commands here are **sub**, **cmp**, and **bne**.  **sub** is the subtract command, and simply subtracts the second argument from the first.  **cmp** is a more interesting command. It compares the first argument with the second, and remembers the result of the comparison in a special register called the current processor status register. You don't really need to worry about this, suffice to say it remembers, among other things, which of the two numbers was bigger or smaller, or if they were equal.[[1]](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok02.html" \l "note1" \o "Note 1)  **bne** is actually just a branch command in disguise. In the ARM assembly language family, any instruction can be executed conditionally. This means that the instruction is only run if the last comparison had a certain result. We will use this extensively later for interesting tricks, but in this case we use the **ne** suffix on the **b** command to mean 'only branch if the last comparison's result was that the values were not equal'. The **ne** suffix can be used on any command, as can several other (16 in all) conditions such as **eq** for equal and **lt** for less than.  2 The All Together  I mentioned briefly last time that the status LED can be turned off again by writing to an offset of 28 from the GPIO controller instead of 40 (i.e. **str r1,[r0,#28]**). Thus, you need to modify the code from OK01 to turn the LED on, run the wait code, turn it off, run the wait code again, and then include a branch back to the beginning. Note, it is not necessary to re-enable the output to GPIO 16, we need only do that once. If you're being efficient, which I strongly encourage, you should be able to reuse the value of **r1**. As with all lessons, a full solution to this can be found on the [download page](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/downloads.html). Be careful to make sure all of your labels are unique. When you write **wait1$:** you cannot label another line **wait1$**.  On my Raspberry Pi it flashes about twice a second. this could easily be altered by changing the value we set **r2** to. However, unfortunately we can't precisely predict the speed this runs at. If you didn't manage to get this working see our trouble shooting page, otherwise, congratulations.  In this lesson we've learnt two more assembly commands, **sub** and **cmp**, as well as learning about conditional execution in ARM.  In the next lesson, [Lesson 3: OK03](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok03.html) we will evaluate how we're coding, and establish some standards so that we can reuse code, and if necessary, work with C or C++ code.   1. [1][^](http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/ok02.html#note1a) I suppose if you've followed the link you really do want to know about it. The CPSR is a 32 bit register consisting of many individual bit fields. It has bit fields for positive, zero and negative. When a cmp instruction is issued, it subtracts the second argument from the first, and notes down whether it is positive, zero or negative with these fields. Zero means the numbers were equal (a-b=0 implies a=b), positive means a is bigger than b (a-b>0 implies a>b) and negative less than. A variety of other comparison instructions exist, but cmp is the most intuitive.   Spot a mistake? You can help improve this tutorial on [GitHub](https://github.com/chadderz121/bakingpi-www).  [Creative Commons Licence](http://creativecommons.org/licenses/by-sa/3.0/deed.en_GB) Baking Pi: Operating Systems Development by Alex Chadwick is licensed under a [Creative Commons Attribution-ShareAlike 3.0 Unported License](http://creativecommons.org/licenses/by-sa/3.0/deed.en_GB).  Based on contributions at <https://github.com/chadderz121/bakingpi-www>. | 第2课 OK02  OK02的课程是基于OK01课程的，所以，很有必要搞懂OK01课。这一课，我们的任务是让“OK”或者“ACT”LED灯周期性亮灭——闪烁。我们假设你实践了OK01课的操作系统代码了。  目录   1. 等待 2. 组装 3. 等待   等待是操作系统开发中一个非常有用的部分，很神奇吧。操作系统经常会发现自己没有事情可做，所以必须等待。在这个例子中，我们想要做的就是让LED灯一亮一灭到人眼可以观察的程度。如果当你刚接通LED灯时就把它关闭掉，我们是无法观察到它的闪烁的。而且计算机可以在一秒内进行开关操作上千次，这样我们就更加难以观察了。在后续课程中，我们会学到精确等待的技术，不过，我们现在的用“干等着”技术就足够了。  （代码）  指令sub reg, #val意思是把寄存器reg中存储的数值减去数值val后所得结果仍在reg寄存器中。  指令cmp reg, #val意思是寄存器reg中的数值和数值val进行比较。  指令后缀ne一般附着在其他指令后面，意思是根据最近一次比较指令产生的结果是否为不相同来决定其所附着的指令的执行。那么，指令bne wait1$意思就是其上一条指令所比较的结果如果是不相等，则跳转（branch）到标签wait1$处下一行执行；如果相等，就什么也不执行。  上面的代码会产生一个延迟。由于每一块树莓派都一样，所以，这个产生的延迟基本上可以说是一样的。 |