Jogging Lap Counter Description **John O'Flaherty** **February 4, 2009**

Summary

In very cold weather, it's more comfortable to jog indoors than out, even given that the track is only about 65 feet long. The boredom is allayed by TV or music. Something was needed to keep track of the distance run, since it's impossible to accurately count a lap every 10 or 12 seconds for 45 minutes. This device does that by detecting the passage of the runner by interruption of ambient light falling on a phototransistor. It keeps count of laps and time, and displays total distance and current lap pace (minutes per mile) in **run** mode, and lap count, total distance, total time, and average pace after the run in **standby** mode and until turn-off.

Choices

It was decided to use a shadow detector of ambient light rather than infrared because it doesn't require as much sensitivity as trying to detect body heat. The shadow detector is a small circuit board with a phototransistor that puts out a pulse on every passage of the runner. Its output is registered by a small, cheap microcontroller evaluation board (Atmel AVR Butterfly, slightly modified). Multiple counts aren't a problem because the microcontroller is programmed to have a refractory period of five seconds after each count, based on the physical impossibility of the runner moving 65 feet in less than five seconds. The entire circuit runs on a 9 volt battery, drawing about 4 mA, and so provides about 125 hours of operation per battery. The circuit is powered through a 5 V LDO regulator, so it will work down to less than 5.5 V battery voltage

Microcontroller

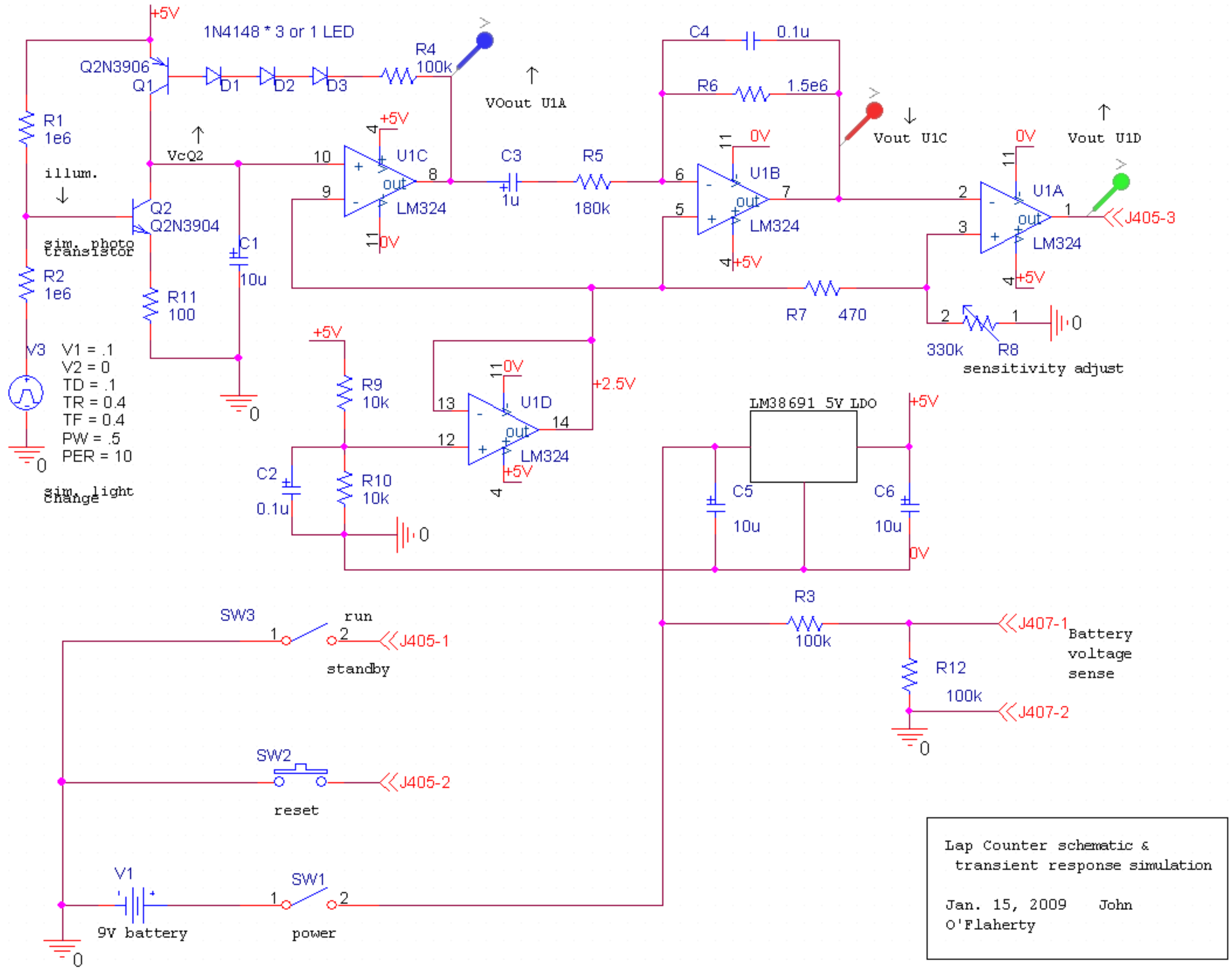
The AVR Butterfly is a demonstration device that costs $19.95, and comes with an ATMega169 microcontroller chip connected to a 6-character LCD display. It comes loaded with software, the source for which has been made available through the efforts of a number of people, notably Martin Thomas for the version that was the starting point for this device. The original software is stripped down to what is necessary to operate the device, and all the historical comments have been deleted or edited, so the code won't look like the barnacle-ridden hull of a long-sunken ship on the ocean floor. Indebtedness to the original writers and modifiers of the software is hereby acknowledged. The code for this project, available on this site, is compiled with the GCC compiler, using AVR Studio software. The Butterfly device can be programmed through the serial port of a computer. Everything that is necessary is freely available on the internet.

The meat of the code is in `LapCounter.c`. The startup routine `main.c` does initialization and clock calibration, enables interrupts, and goes into an eternal spin loop. All the operation of the device occurs in the interrupt service routine, in `LapCounter.c`. The `ADC.c` file has been modified to have inline assembly code, which does what the commented-out C code would do, just because the way the C code gets compiled involves some strange register-dithering that I found esthetically offensive; also, it was an experiment in converting it to assembly. The `LCD_driver.c` file was modified to provide some extra characters, and it also shows a matrix for making up characters. There is a line in `LapCounter.c`, that defines LAPLENGTH in feet, and it can be set as desired before compiling. For my purposes, there was no use in making that modifiable in the working device. All the arithmetic is based on feet, miles and seconds.

There are a few physical modifications to the Butterfly board. The dataflash eeprom is removed since it is a 3 V device and this circuit operates on 5 V (the microcontroller itself is good for 5 V). The clip for the 3 V lithium battery is also removed, though it could be left in place. Some voltage divider resistors and diodes are removed from the J407 voltage sensing input. A couple of other resistors are added, which could as easily go onto the shadow sensing circuit board. These changes are shown on the "OPEN BACK" photograph.

Operation

The lap counter should be set up close to the path of the runner, so that there will be a good interruption of the ambient light falling on the sensor. When the **standby**/**run** switch is set to **run**, the unit will be sensitive to shadows after an initial refractory period of five seconds, allowing the runner to get away. The unit will alternately display total distance and lap pace for the last lap. When the switch is in **standby**, data is retained, but time and counts are not accumulated. In **standby**, the display automatically cycles through total distance in miles, total time, average pace, and total counts. The **reset** switch resets counts and time to zero, but it is only effective in **run** mode, to prevent inadvertent loss of data. If **reset** is pressed in **standby** mode, the display will show battery voltage for several seconds. While in **run** mode, as the runner passes and triggers the sensor, the piezo beeper sounds, giving confidence that the setup is working correctly.



Description of light detector circuit

An NPN phototransistor (Q2) is connected in series with a PNP transistor (Q1) which acts as a constant current source. The base of Q1 is driven by the output of an op-amp (U1C), whose non-inverting input is connected to the collectors of the transistors. The inverting input is connected to V+/2. The operation of the circuit is such as to maintain the phototransistor collector at approximately V+/2 over a fairly wide range of illumination levels, and so maximize its sensitivity to changes in light. The low-light performance is still limited by the dark current of the phototransistor, when noise is stronger than light input. The emitter resistor in the phototransistor isn't for degeneration, since the base voltage is undefined; rather, it's to prevent damage or battery depletion in case the unit is left on in the presence of very strong light. The diodes D1 through D3 are a means of shifting voltage so that the LM324, which is not a rail-to-rail device, is in a more comfortable operating range, and can completely turn off Q1 if called to. (The first choice for an op-amp was a TLC2274, a rail-to-rail CMOS op-amp, but its quiescent current drain was several times that of the LM324.)

The output of the circuit from U1C is AC-coupled to U1B, which acts as a bandpass filter/amplifier centered around 1 Hz. This seemed a reasonable choice for picking up the shadow of a passing runner, while rejecting slower and faster changes in illumination. The output of this filter/amplifier is fed to U1A, which acts as a comparator. The output of this stage goes to an input on the microcontroller. The sensitivity of the circuit can be adjusted by changing the DC level on this stage's non-inverting input. The remaining stage of the 324 supplies a stable V+/2.

The LDO regulator, LM38691, provides +5V to operate both the shadow detector and the microcontroller.

The battery is connected through the power switch to the input to the regulator, and through a voltage divider to an A/D input port on the microcontroller, which allows checking the battery voltage.